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BILATERAL LOBECTOMY FOR BILATERAL BRONCHIECTASIS

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AS THE mortality of lobectomy for unilobar bronchiectasis has declined to a present level which seems almost incredibly low (less than 1 per cent in a recently reported series) the indications for the operation have been extended to include two types of cases which in the past were rejected; namely, (1) cases of minimal disease with symptoms not troublesome enough to warrant any considerable risk of operation, and (2) cases of diffuse disease, with involvement of both lungs or of both the upper and the lower lobe of one lung. This paper is not concerned with cases of the first type, those of minimal disease; suffice it to state that radical curative treatment is justified in such cases in anticipation of the inevitable progress of the disease, with increasingly distressing symptoms and with probability of considerable shortening of the life expectancy.

In cases of the second type, those of multilobar disease, there is a more urgent need of surgical intervention because in general the more widespread the disease the severer the symptoms. Patients with extensive bronchiectasis not only are invalided early in life but suffer even more from the psychologic effect of being more or less ostracized from society, and usually they do not live beyond middle age.

The mortality of lobectomy for bilateral disease is higher than that for unilateral disease, for several reasons. One of the hazards of lobectomy is the spillage of pus and secretions into the bronchial tree during operation. This purulent sputum may drown the patient, literally, or may cause death later from pulmonary complications arising from aspiration of the material into the uninvolved lobes of the lungs. As a rule, this hazard is greater in the cases of bilateral involvement because there is a larger quantity of pus with which to cope. Furthermore, in cases of unilateral involvement all disease is eradicated at the time of the original operation, but in cases of bilateral bronchiectasis a portion of the diseased and pus-containing bronchi remain to complicate convalescence. For several days coughing is painful and restricted, and drainage of the residual bronchiectasis by expectoration is not completely

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effective. Consequently, there is a higher incidence not only of atelectasis and other pulmonary complications but of bronchopleural fistula and empyema. Finally, if the hazards are reduced merely to a basis of chance, bilateral lobectomy implies two operations and twice the risk. It is not surprising, therefore, that in 37 cases of bilateral lobectomy collected from the literature (Bradshaw and O'Neill,[1] 17 cases; Churchill,[2] 5 cases; Blades and Graham,[3] 4 cases; Ross,[4] 2 cases; Eloesser,[5] 1 case; Lewis,[6] 1 case; Edwards,[7] 1 case; Overholt,[7a] 1 case; Ingraham,[7b] 1 case, and we, 4 cases, there were 5 deaths, a mortality of 13.5 per cent.

Removal of two major lobes, either total pneumonectomy or bilateral lobectomy, reduces the amount of lung tissue available for respiratory function so drastically that the cardiorespiratory capacity must be critically evaluated before each operation. It is interesting that in 3 of our 4 cases the resections did not cause reduction in vital capacity but, on the contrary, produced sizable increases. Apparently, the bronchiectatic lobes were relatively functionless. This is understandable in cases in which the diseased lobes are small, contracted, atelectatic, functionless masses. After lobectomy the residual normal lobes become emphysematous and apparently develop some increase in respiratory capacity. To realize fully the benefits of this compensatory change, three or more months should be allowed between stages of operation. Probably the principal factors responsible for increasing respiratory capacity are the elimination of infection and of coughing and their interference with respiratory efficiency. The reduction in cardiac and respiratory reserve which occurs with aging limits the use of bilateral lobectomy to children and young adults, a younger age limit than that for unilateral lobectomy.

In an article entitled "With How Little Lung Tissue Is Life Compatible" Graham [8] reported a case in which he removed the lower and middle lobes of the right lung and the lower lobe and the lingua of the

1. Bradshaw, H. H., and O'Neill, J. F.: Surgical Treatment of Bronchiectasis, Surg., Gynec. & Obst. **77**:315, 1943.

2. Churchill, E. D.: Resection of Lung, Surgery **8**:961, 1940.

3. Blades, B., and Graham, E. A.: Surgical Treatment (Lobectomy) of Bilateral Bronchiectasis, Surg., Gynec. & Obst. **75**:457-464, 1942.

4. Ross, D. E.: Bilateral Lobectomy (Presentation of Two Cases), Canad. M. A. J. **39**:549-552, 1938.

5. Eloesser, L.: Bilateral Lobectomy, Surg., Gynec. & Obst. **57**:247-249, 1933.

6. Lewis, I.: Bilateral Lobectomy for Bronchiectasis, Brit. J. Surg. **24**: 362-367, 1936.

7. Edwards, T., cited, Pneumonectomy, Foreign Letters [Paris], J. A. M. A. **107**:1650 (Nov. 14) 1936.

7a. Ingraham, R.: Case of Situs Inversus with Extensive Bilateral Bronchiectasis Dating from Early Childhood and with Bilateral Lobectomies, M. Women's J. **46**:593-598, 1939.

7b. Overholt, R. H.: Bilateral Trilobectomy: Report of Successful Case, J. A. M. A. **109**:127 (July 10) 1937.

(Footnotes continued on next page)

upper lobe of the left lung, in two stages. Two months after the second operation the boy had a vital capacity of 1,200 cc. and was leading an active life, without dyspnea. In 1 of our cases the middle lobe of the right lung was removed, in addition to the lower lobes of both lungs, and the patient is leading a much more active life than was possible before operation.

It is our purpose to record 4 cases of bilateral bronchiectasis cured by bilateral lobectomy. In all the lower lobes of both lungs were removed and in 1 case the middle lobe of the right lung was also excised. In all but case 2 the patients are entirely free from symptoms. In case 2 there is some residual cough and sputum because the middle lobe of the right lung and the lingua of the upper lobe of the left lung are bronchiectatic, and the disease remains because it was not recognized prior to and at operation. Eight operations and 9 lobectomies were performed in the 4 cases—all by intralobar dissection and the individual ligation technic, with intratracheal cyclopropane anesthesia and frequent intratracheal aspirations. In 2 cases bronchopleural fistula with empyema developed, in each case after the first stage of operation, and in both cases the fistula closed spontaneously after drainage of the empyema. There were no deaths in this small series.

In no other type of surgical case does a successful outcome depend so much on constant observation and vigilant attention to details of preoperative, operative and postoperative care. Our patients had the constant attention of special nurses trained to encourage coughing and alert to any interference with a free airway. A resident surgeon skilled in tracheobronchial aspiration was always immediately available. The hemoglobin and the red cells were maintained at normal levels by the liberal use of blood transfusions before, during and after operation. The tracheobronchial tree was kept free of sputum as completely as possible by postural drainage before operation and by frequent tracheobronchial aspirations during and after operation. Chemotherapy was utilized prior to and after operation, first, with the sulfonamide drugs and, later, with penicillin, when it became available. Oxygen was administered in a tent as long as the patient felt that it was beneficial.

Of inestimable importance is the fact that all the patients are enjoying not only good health but normal lives, which the cough previously denied them. The 2 boys have resumed schooling, which they had been compelled to give up, and the maiden has married.

REPORT OF CASES

CASE 1.—R. H., a youth aged 19, had pneumonia at the age of 3 and since then had had a chronic cough productive of as much as 10 ounces (300 cc.) of sputum daily. At times the sputum had an odor but had never contained blood. He had had

8. Graham, E. A.: With How Little Lung Tissue Is Life Compatible? Report of Patient from Whom All Pulmonary Tissue Except Two Upper Lobes Was Successfully Removed, Surgery **8**:239-246, 1940.

pneumonia twice, the last time after tonsillectomy. For several years he had been chronically fatigued and abnormally dyspneic on exertion, and he was depressed because his cough made it impossible to continue in school and caused "people to look at [him] as though [he] had T. B." He stated that life was not worth while unless he could be rid of the cough and that he was willing to accept a considerable risk in prospect of a cure.

The abnormal physical findings were underdevelopment, clubbing of the fingers and toes, a moist cough and coarse rales at the base of both lungs. The laboratory findings were normal except for leukocytosis, with a count of 12,400, and the roentgenographic evidence of bronchiectasis of the lower lobes of both lungs and the middle lobe of the right lung. In the standard anteroposterior roentgenogram there were triangular areas of increased density at both bases medially, and in the bronchograms there was saccular dilatation of the bronchi of the lower lobes of both lungs and the middle lobe of the right lung. The vital capacity was 2,500 cc.

On Aug. 21, 1942, after four days of postural drainage every three hours, forced feeding and administration of sulfadiazine, 4 Gm. daily, the lower lobe of the left lung was removed by the individual ligation technic through a posterior lateral incision carried through the bed of the seventh rib. The bronchial stump was closed with a central ligature, two mattress sutures and a row of interrupted sutures, turning the cut edges. The stump and the pleural cavity were dusted with 5 Gm. of sulfanilamide crystals. Expansion of the upper lobe to fill the chest cavity was immediately obtained and maintained by means of constant suction applied through two air-tight catheters left in the pleural cavity.

A transfusion of 500 cc. of blood and 500 cc. of dextrose in saline solution was given during operation and 1,000 cc. of 10 per cent dextrose in distilled water a few hours after operation. Subsequently, water balance was maintained by oral administration. Five hundred cubic centimeters of blood was given on the day following operation. The patient was in an oxygen tent for two days, and tracheobronchial aspirations were done two to five times daily for four days. A daily dose of 3 to 5 Gm. of sulfadiazine was given for five days after operation. The catheters in the pleural cavity were removed on the sixth day, and convalescence was uneventful until the tenth day, when there developed evidence of increasing fluid in the left side of the chest and expectoration of large quantities of thick, yellow sputum. On the thirteenth day the wound bulged in its lower portion; when it was opened, a large quantity of pus escaped. Since drainage was not dependent, a segment of the eighth rib was resected for open drainage two days later. Constant suction was applied, and in five days the bronchial fistula had closed, and seven days later the thoracotomy wound was healed and the patient discharged from the hospital.

On Jan. 15, 1943 the patient returned for the second operation. There had been notable reduction in the quantity of cough and sputum. The vital capacity was 2,250 cc. On January 18 the lower and middle lobes of the right lung were removed by intralobar dissection and the individual ligation technic, as in the previous operation. Tracheobronchial aspiration was done only once on the evening of operation. Convalescence was uneventful, and the patient was discharged from the hospital twelve days after operation. The care was essentially the same as that given at the first stage.

When last examined, eighteen months after the second operation, the patient had no cough, felt that he had normal, good health and had gained 20 pounds (9 Kg.) in weight. He was normally active, without dyspnea and fatigue, and had graduated from high school. His vital capacity was 2,500 cc.

CASE 2.—A. S., a girl aged 19, complained of a chronic cough productive of 4 to 8 ounces (125 to 250 cc.) of thick, yellow sputum daily for a period of three

years, following pneumonia. At no time had the sputum contained blood or had an odor. She had lost weight and strength and had been compelled to drop out of high school. A year previously radical operations had been performed on both maxillary sinuses.

Physical examination revealed no abnormality except for slight clubbing of the fingers and coarse rales over the bases of both lungs posteriorly. Laboratory findings were normal, and the vital capacity was 1,650 cc.

Bronchograms revealed cylindric bronchiectasis of the lower lobe of the left lung and saccular bronchiectasis of the lower lobe of the right lung. The bronchi of the other lobes were filled and were normal.

On Jan. 9, 1943 the lower lobe of the right lung was removed, and on June 6 the lower lobe of the left lung was resected. Both operations were performed through the beds of the resected seventh ribs and both by intralobar dissection and the individual ligation technic. In both instances convalescence was uneventful, but was more trying and prolonged after the first operation on account of the cough. The general plan of care was the same as that in case 1.

Because the patient was not entirely relieved of cough and sputum, bronchograms were made six months after the last operation. These studies showed residual saccular bronchiectasis in the middle lobe of the right lung and in the lingua of the upper lobe of the left lung. The disease in these lobes had been overlooked in the original bronchograms, owing probably to the distortion resulting from the complete atelectasis of both lower lobes.

The patient has refused to have another operation for removal of this residual disease because she feels quite well and the cough and sputum have been reduced to an amount which she considers inconsequential. She married two years after her operation. The vital capacity at the time of the last examination was 2,000 cc.

CASE 3.—L. J., a youth aged 15, entered the University Hospital immediately after a gross hemoptysis. He gave a history of chronic productive cough following pertussis at the age of 1 year. The sputum at times had been foul, but there had been no previous episodes of hemorrhage. At 8, and again at 10 years of age, he had had pneumonia. Because exertion excited paroxysms of coughing, he never had been able to participate in athletics.

Examination revealed a thin but well developed lad with much clubbing and slight cyanosis of the fingers and toes. There were diminished excursion of the left hemithorax and dulness, rales and diminished breath sounds throughout that side. At the base of the right lung were coarse rales.

Laboratory studies showed nothing abnormal except for anemia (hemoglobin, 9.5 Gm. per hundred cubic centimeters, and red blood cells, 3,260,000).

A standard roentgenogram of the chest showed patchy areas of increased density throughout the left lung, elevation of the left side of the diaphragm, narrowing of the intercostal spaces on the same side and some displacement of the trachea to the left, interpreted as patchy atelectasis from recent hemorrhage. In the right cardiophrenic angle was a triangular area of increased density.

Bronchograms, made eight days after admission, revealed pronounced saccular bronchiectasis of the lower lobes of both lungs. The bronchi of the remaining lobes appeared normal. At this time the vital capacity was 2,400 cc.

Normal values for hemoglobin and the red blood cells were established with transfusion of 700 cc. of blood, and on Aug. 3, 1944 the lower lobe of the left lung was removed by the technic previously described. Penicillin, 150,000 units daily, was administered intramuscularly four days prior to and seven days after operation. A bronchopleural fistula with empyema developed on the tenth day, and drainage

was established two days later. Closure of the fistula and empyema cavity was accomplished in eighteen days.

On Feb. 10, 1945 the lower lobe of the right lung was removed by the technic previously described, and convalescence was uneventful.

A year later the patient was well, entirely free of cough and leading a normal life as a high school student. He had gained 28 pounds (12.7 Kg.) and his vital capacity was 2,800 cc.

Case 4.—D. W., a housewife aged 23, had a chronic productive cough which followed whooping cough in infancy. At times she had raised as much as 12 ounces (360 cc.) of sputum daily, and frequently it had an offensive odor. On six occasions during the past two years she had coughed up from 4 to 8 ounces (125 to 250 cc.) of blood in the course of a few minutes, and often the sputum had been blood streaked. During this period she had lost 20 pounds (9.1 Kg.) in weight and had been unable to work. One year prior to consultation she was hospitalized for four months in a tuberculosis sanatorium. On two occasions, nine and six years prior to examination, she had had pneumonia.

Examination revealed a pale poorly nourished and underdeveloped woman, appearing much older than her years. There were moderate clubbing of fingers and toes and coarse rales at the base of both lungs. Both lobes of the thyroid gland contained small adenomas.

Laboratory studies gave normal results. The vital capacity was 2,100 cc.

The lower lobe of the left lung was removed March 11, 1946, and the lower lobe of the right lung, on May 23, 1946. Both operations were performed through an intercostal incision without resection of ribs and by intralobar dissection and the individual ligation technic. Penicillin was administered before and after operation, as in case 3.

Convalescence after each operation was uneventful, and the patient has reported that she feels well and has been free of cough since the last operation.

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DISCUSSION

Dr. Joseph W. Gale, Madison, Wis.: Dr. Bisgard and Dr. Swenson are to be congratulated on their excellent results with bilateral lobectomy. Patients such as those reported on, with diffuse bilateral bronchiectasis, present not only the greatest dangers, but the greatest difficulties, in salvage. They have suffered from a long-standing chronic infection, and all have some degree of amyloidosis. The entire bronchial tree is constantly bathed with a copious, putrid, purulent exudate, which is capable of inciting acute exacerbations in the form of pneumonitis, pulmonary abscess and atelectasis.

The authors have given several reasons for the high operative mortality and have enumerated some of the methods employed to combat it. Since the problem of pulmonary resection, unilateral or bilateral, is gaining increasing attention, I feel justified in making a few additional suggestions which my associates and I have found of great value in our handling of patients undergoing this operation. The authors have mentioned the importance of preoperative and postoperative care, and we are in entire agreement with their conclusions. When we approach these cases, we determine the susceptibility of the organisms to the sulfonamide drugs and to penicillin. Before operation we frequently place our patients under treatment with both drugs. We usually employ sulfadiazine four to seven days prior to operation. A dose of 4 Gm. is given daily, care being taken to force

fluids and to watch the urine. Before operation penicillin in the form of a spray is given by inhalation every two hours, the patient receiving 200,000 units daily. Only penicillin in crystalline form dissolved in distilled water is used. It is most important that only an atomizer providing a very fine spray be employed. All preparations of penicillin other than the crystalline form have proved undesirable, chiefly because of the pungent uriniferous odor which they impart to the air of the ward and to the patient. Most patients refuse to use them. Postural drainage is probably the most important preoperative measure and must be employed frequently and effectively for several days prior to operation, and continued until the amount of sputum is reduced to a minimum, as judged by a low level of expectoration for several days. The patient should be given postural drainage just before coming to the operating room, and great care must be taken during the operation to prevent spillage into the opposite lung. If the patient is operated on while lying on his side, a Trendelenburg position should be assumed and an open airway maintained throughout the procedure, accompanied with aspiration of the trachea by catheter. If the patient is placed in the prone position, the same technic should be employed. Immediately after operation bronchoscopic examination and careful aspiration under direct visualization should be performed on all patients. It is surprising how much secretion can be removed by this method, even though apparently effective aspiration was carried out throughout the operation. Our patients are all given oxygen by intranasal inhalation after operation and may be permitted to sit in a chair while still receiving this therapy. We feel that it is more adaptable to free movement than is the oxygen tent. In our last series, of 51 lobectomies for bronchiectasis, we have had 2 deaths, 1 directly attributable to spillage of pus into the opposite lung. This occurred in spite of all precautions enumerated. The other patient died after a reaction to transfusion. In this series of patients we encountered only 2 who needed bilateral lobectomy. It has been our experience that many patients will show such great improvement in the opposite lung after operation that they will not permit further surgical treatment. There are a few, however, who will require the bilateral operation. It has been our practice to attack the side of the greatest involvement in the first procedure.

Such operations as have been described by the authors would have been ill advised, and next to impossible, less than a decade ago. The intralobar individual ligation of the vessels, accompanied with efficient closure of the bronchus and reenforced by careful preoperative and postoperative medication and care, has rendered this operation safe.

DISCUSSION

Dr. Thomas J. Kinsella, Minneapolis: I congratulate Dr. Bisgard and Dr. Swanson on their excellent work. It takes a great deal of courage and skill and a well coordinated team to handle this type of work successfully. Bilateral bronchiectasis, by and large, is not suitable for surgical treatment. Many patients have too extensive involvement to permit successful resection with recovery.

The patient must be studied carefully and adequate bronchograms made, so that the surgeon may know what he is dealing with before he operates. Inadequate bronchograms will often deceive the surgeon. He will find after the operation that he has overlooked involvement of the upper lobe and that the patient still has symptoms.

I agree with Dr. Gale that many of the patients who have bilateral bronchiectasis are willing and happy to go along without their second operation. Resection of the most diseased lung may be followed by sufficient improvement to satisfy both patient and physician. There should be a considerable interval between the

attack on the first side and that on the other. It may take the patient several weeks or months to regain his breathing capacity on the side of operation. If the operations are done too close together, the patient is subjected to too great a strain on his cardiovascular system.

One must be careful about performing bilateral resections on older persons. This work should be limited to children and young adults, who have more or less elastic lungs, but even they should not be left with such a reduced vital capacity that they become respiratory cripples.

One must realize that the Trendelenburg position alone does not protect the patient against aspiration of sputum into the opposite lung. With the patient in the Trendelenburg position, particularly in the lateral decubitus position, secretions may easily run from the lower lobe on the side of operation to the upper lobe of the opposite lung and cause considerable trouble. That is particularly true during mobilization of the lower lobe.

Adequate preoperative preparation and postoperative care are essential in this field. The patients are a hazardous group to tackle, and the authors are to be congratulated on their excellent results.

DR. CLIFFORD C. NESSELRODE, Kansas City, Kan.: May I ask Dr. Bisgard that, in opening the final discussion, he give us an estimate as to the time elapsing between the two operations? He inferred that the patient went home for two or three months. In other words, he made no mention of the time that elapsed between the two operations.

DR. J. DEWEY BISGARD, Omaha: I thank the discussants for their contribution. With regard to Dr. Gale's comment on the position of the patient on the table, I operate with the patient sitting up; I feel that, since the disease is confined to the lower lobes, the bronchial secretions are less likely to get into the upper lobes with the patient in this position. Graham pointed this out.

I have 3 patients with bilateral disease on whom I have operated with the intention of doing a bilateral lobectomy, and I have removed, as I always attempt to do, the most diseased lobe first. These patients are happy with the result obtained from the removal of one lobe and do not wish to have the second operation. I think that is not an uncommon experience.

About three months is the least time that has elapsed between the two operations —from three to six months—and I agree with Dr. Kinsella that it is well to allow this time for the remaining lung to become emphysematous and adjusted to the expansion necessary to fill the chest. I am sure that emphysematous lungs gain respiratory capacity in time. I think that also answers Dr. Nesselrode's question.

SEAMLESS PROSTHETIC HANDS: A TECHNIC OF FABRICATION

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I. THE MAKING OF THE MOLD

THE MAKING of naturalistic, seamless, prosthetic hands of plastic materials such as rubber latex and Plastisol has presented numerous difficulties. We have not been able to find any evidence of plastic materials such as gelatin being employed for prosthetic hand making. When it became common practice to compound rubber latex in this country, one of us (C. D. C.) experimented with this material for making prosthetic hands and facial features. Molds of plaster, agar, rubber, metal and wax were used. The agar mold first seemed to be the most logical, because by the use of this material a comparatively seamless cast could be produced. However, the mere fact that a new agar mold, or negative, had to be made for each positive, or cast, caused this material eventually to be discarded. Early experiments about eighteen years prior to the writing of this paper with gypsum cements and low fusing metals produced good molds for prosthetic hand casts, but invariably the molds had to be made as two or more pieces. The r[illegible]lting casts would be defaced with unsightly seam lines where the pieces of the mold joined. Nevertheless, more than one cast could be obtained from a single mold. To get away from these seam lines, the wax positives were made from seamless agar molds, which in turn were heavily electroplated with metal to form metal molds. From these, seamless rubber prostheses were produced. At this early date the plasticized or resilient resins had not been discovered. Nevertheless, the necessity of making an agar mold, then a wax positive, then a metal mold and finally the rubber cast created too many steps in the development. The final result invariably suffered from the multiplicity of processes. To eliminate this difficulty metal molds were electroplated directly onto hands from fresh cadavers. The hand was then

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removed from the resulting mold by maceration. At that time, before social security, cadavers were comparatively easy to obtain. This method was eventually discarded in spite of the fact that it gave good one piece molds. When it was learned how to build up coagulum deposits of rubber on agar molds, just prior to the past war, the use of one piece agar molds for making seamless rubber hands was revived. At that time the major portions of the book "Facial and Body Prosthesis" were written to fulfil a contract with the publisher. As a result of shortages, this book did not leave the presses until the last year of the war.

In the last few years further experiments with one piece rubber and metal molds have been carried out, the results of which are now being reported.

SHRINKAGE OF RUBBER

Before the discovery of the resilient resins, rubber was the best material for use in the making of naturalistic prosthetic appliances. In the case of hands being made in nonabsorptive molds, such as those of agar and metal, rubber presented a decided difficulty. Its extreme shrinkage on forming in such molds was a definite disadvantage. The resulting seamless hand of an adult, though perfect in details, would appear to be that of a child. Experiments were therefore begun to find ways of enlarging these hands. At first the vulcanized latex hands were swelled in benzene and then remolded in plaster for succeeding rubber casts. It was then found that by soaking the hands in a solution of liquid petrolatum and oil-free naphtha they could be enlarged and fixed at practically any desired size without an appreciable loss of strength or detail. The final size of the hand was determined by the amount of liquid petrolatum in the oil-free naphtha. About 20 per cent was generally sufficient. The hands were simply soaked in this mixture until they reached huge but naturalistic proportions. They were then carefully removed and dried on clean blotting paper. The oil-free naphtha volatilized, leaving the nonvolatile oil infused into the cast. Experiments were also run on castor oil as an enlarging agent, because this oil has little or no deleterious effect on rubber. It has also been found that by soaking the rubber cast, fresh from the mold, coagulated and wet, in the naphtha mixture there is far less tendency for the unfilled rubber cast to turn dark. This has always been a difficulty to overcome with rubber prostheses.

THE RESILIENT RESINS

With the discovery of the resilient resins, it was found that these materials resisted the darkening effect of sunlight more readily than rubber. Rubber mixtures in which the filler content is kept low enough to produce the same translucency will invariably darken on extensive

exposure to sunlight. Furthermore, the shrinkage of the resilient resins was negligible, even when cast in nonabsorptive molds. However, the first resilient resins to appear on the market were extremely weak in comparison to rubber, and, furthermore, they were more difficult to use. For this reason, we continued to experiment with both materials to arrive at definite conclusions about each. At the present, one material is fully as important as the other. Rubber serves best for making molds of hands, while the new improved and stronger resilient resins serve better for the actual prosthetic hand. However, the problems of compounding the materials and the mechanics of making molds and casts with these new materials have been many. It is surprising to find that even today most prosthetists employ piece molds, which result in casts with seam lines around each finger and up the sides of the wrist.

THE MAKING OF THE SEAMLESS MOLD

As a result of the average prosthetic hand being worn over a mechanical device and the fact that the wrist is kept under a coat or dress sleeve, the hand is seldom made to extend more than 5 or 6 inches (12 or 15 cm.) above the joint of the wrist and hand. However, this does not mean that the entire arm cannot be cast. Indeed, by the method to be described, we have cast entire arms as seamless prostheses. Such prostheses are desired by women for evening wear when the arm or most of it is exposed. Where the stump of the natural arm is between the shoulder and elbow, the prosthesis can be made to fit at this juncture. Join lines can be hidden beneath broad bracelets. In this way, low-cut evening gowns exposing the shoulders may be worn.

Before one attempts to make the mold, the hand and wrist are shaved to about 1 inch (2.5 cm.) above the point where the prosthesis is to begin. Care should be taken that the skin is not cut, because every defect will be reproduced in the mold—even old scars and the fingerprint pattern. Furthermore, if a cut bleeds during the molding process, a considerably larger area of the detail will be lost.

A suitable glass or enamelware receptacle of sufficient depth to take the hand and wrist is secured. This must have a neck whose diameter will allow easy passage of the hand with extended fingers. Should the fingers be allowed to come together during succeeding dippings, the rubber surfaces will probably stick. Of course, this may be prevented by giving the hand a coating of talc after each drying and between each dipping. However, this is not necessary, and nothing must be done to cause one coat of rubber to separate from a succeeding coat. If the mold is not properly made, this may happen during the curing of the cast. The receptacle is filled with vulcanized latex. This can be pure Vultex [1]

alone, such as H222, or it can be filled up to 20 per cent by volume with such fillers as cork dust, dixie clay, wood flour or Vultex filler H222 part B. We prefer to use the Vultex filler, because it contains a sufficient amount of zinc oxide to thicken the latex, giving heavier coats. However, the latex mix must not contain more than 20 per cent filler.

Fig. 1.—*A*, the subject's old type prosthetic right hand, covered with a glove, and his normal left hand. *B*, a comparison of the patient's right hand with that of the donor. *C*, the donor's hand is shaved of hair in preparation for making the mold. *D*, the hand is then dipped into the latex mixture.

Otherwise, the resulting mold will become stiff and more difficult to remove from the final prosthetic hand.

The bubbles that collect on the surface of the latex mix should be allowed to disappear or be expelled with the flame from a Bunsen burner. These air bubbles gather in the liquid during mixing or pouring. If

the hand is dipped into the mixture while the bubbles are on the surface, they are sure to collect on the hand and may destroy some of the final details of the mold. However, if they are broken by air blown on the dipped hand, the second dipping will fill the uncovered areas left by the broken bubbles.

The hand is dipped for the first time. No previous preparation of the skin other than shaving is necessary, as the finished rubber mold separates readily from the hand on drying. The fingers must be held well apart to prevent sticking. Furthermore, they should be relaxed but comparatively straight. One would reason that the fingers should assume a bent position, as when they lie at rest. This is a fallacy, because once they are made as positives in the plastic rubber, vinyl chloride or other resilient resins they may be bent into any desired position. If the mold is made over bent fingers, the deep depressions and folds of the skin are recorded both in the negative and in the positive and are not lost, even when the fingers of the positive are straightened. However, these bends or folds will appear in the bent prostheses if the fingers are molded straight.

After each dipping the hands are allowed to drain back into the receptacle until only a slow drip is apparent. The hands are then removed and held over a heating device such as a gas flame or an electric heater to aid in drying. Care must be taken not to get the mold warm enough to burn the donor.

Twisting of the wrist or movement of the fingers should be kept at a minimum as the latex dries. Otherwise, a spiral distortion may appear at the wrist. If the latex forms drops or thin areas in spite of shaking, these can be painted over with a brush. In fact, a brush dipped in latex can be used to advantage to extend the mold up the arm should the dipping receptacle not be deep enough. The hand may be held above the head or in any desired position so long as it is not twisted or bent at the wrist.

If molds are to be made in quantity production, it is a good practice to have a drying cabinet constructed with openings at the top into which the donor may insert his hand. It generally takes from six to eight dippings to make a mold of sufficient thickness to be used. If the mold is too thin, it will be drawn out of shape by the weight of the material used in the positive on drying or curing. If it is too thick, it is difficult to remove the positive from the negative. The average time consumed in making a good one piece rubber mold of a hand is from two to four hours. However, there are methods by which this time factor can be greatly reduced.

When the third coat has dried, the edges of rubber where the mold joins the skin of the arm are loosened and rolled down for about ½ inch (1.27 cm.) until they form a circular cuff. The dried rubber will stick together during this rolling process to form the cuff.

At this point it is also advisable to attach the grommets or rings for suspending the mold during the pouring, drying and curing of the positive. These can be held with a pair of forceps or hemostats, dipped

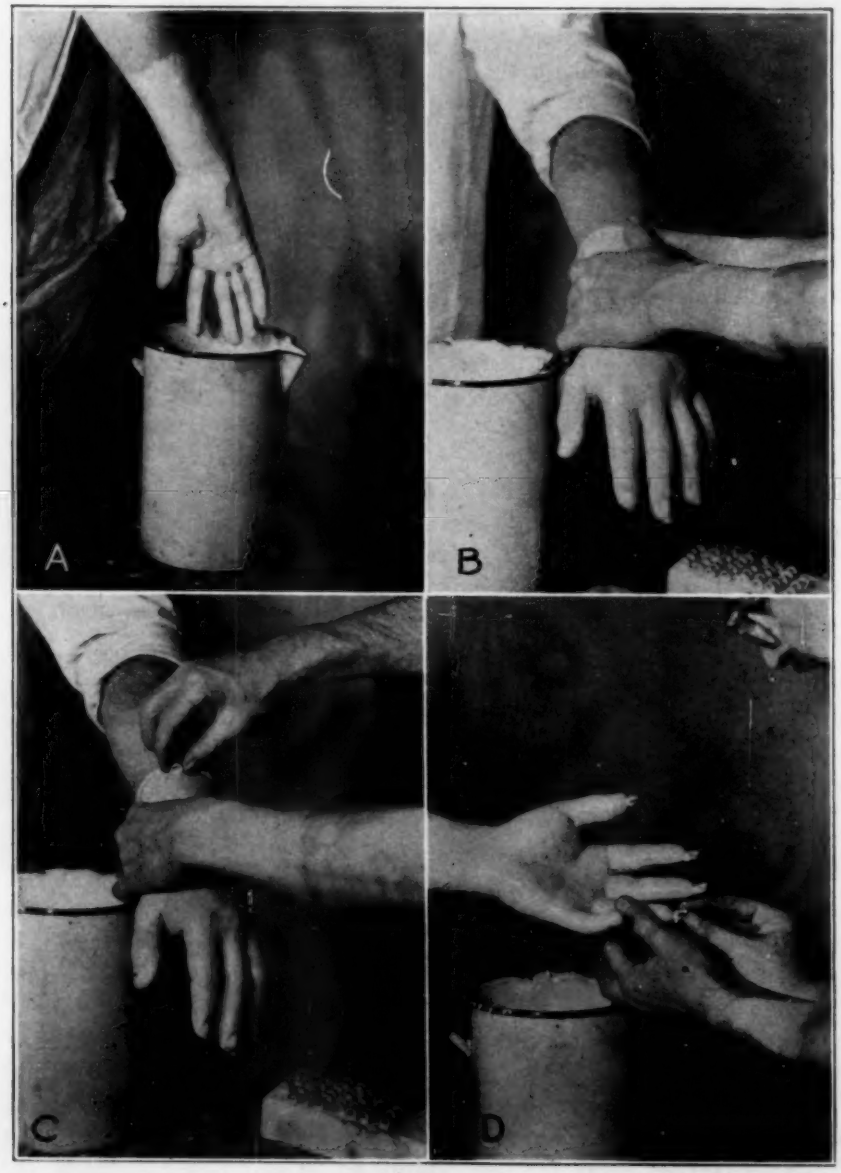

Fig. 2.—*A*, after each dipping the hand is allowed to dry. This is accelerated over an open flame gas burner or electric heater. *B*, to create the cuff, the top edge of the mold is rolled down about three times. This is done after the third or fourth dipping. *C*, the hanging rings are dipped in latex and applied to the rolled cuff. *D*, a hanging ring can be put on the end of each finger. However, one or two on the middle fingers are sufficient.

individually into the latex mix and then placed on their edge on a block of plaster of paris to dry. After a few minutes, they will have dried with a facet at their base. This facet is dipped in latex and held in place at each finger tip and on the rolled cuff of the rubber mold. They stick immediately. In a few minutes, the dipping can be continued to build up the desired thickness to the mold. The subsequent dippings will cover the attached rings and further incorporate them within the body of the mold.

When the last dipping is thoroughly dry, the mold should be dusted with talc to keep it from sticking together on the removal of the hand. The mold is then grasped by the ringlike cuff and pulled away from the donor's hand, which separates without difficulty. However, should any attempt be made to remove the mold before it is thoroughly dry, it will either tear or be stretched out of true proportion. It is best to allow the mold to dry further for a few hours at room temperature or a few minutes in an oven at 90 C. to be sure of complete drying. Before it is used for the positive, the mold should be turned inside out and thoroughly washed with warm soapy water, after which it is ready to use, for a rubber or resilient resin cast.

CARE AND TREATMENT OF MOLDS

The rubber mold when not in use should always be hung by one of the rings at the wrist end. Cup hooks serve admirably for this purpose. Molds should never be laid or stacked away, as this causes them to lose their shape.

The making of the positive rubber and resilient resin casts will be discussed in the following sections.

II. PROSTHETIC RUBBER HANDS

As mentioned at the end of the previous section, when the rubber mold is removed from the donor and the rubber is thoroughly dry, it is washed inside and out with soap and water and then allowed to dry again. In making rubber casts in rubber molds, one is faced with two major problems. The first is that of separating the cast from the mold. Rubber casts can be separated from rubber molds without difficulty if the proper separating medium is used. In preparation of the mold for rubber casting, the separating medium is applied first and allowed to dry. Then the coagulating agent is put on and also allowed to dry before the rubber latex is poured into the mold. The second problem is to build up a uniform thickness of rubber against the mold which is nonabsorptive. Generally this deposit is about ⅛ inch (0.32 cm.) in thickness. It is achieved by application of a thin layer of a coagulating agent to the mold. If the mold were of porous, dry, gypsum cement, such a deposit could be built up by absorption of water into the mold from the rubber. Since

Fig. 3.—*A*, after the last dipping, the outer surface of the mold is treated with talc to prevent sticking of the surfaces on removal. *B*, the mold loses its gloss after talcing. *C*, the mold is stripped from the patient. *D*, it is turned inside out in the stripping process.

there is no such absorption into a rubber mold, the coagulating agent is necessary.

SEPARATING MEDIUMS

Shellac or laquer serve well for a separating medium. However, both must be diluted considerably with their proper solvents before use. Furthermore, the solvents must be chosen which will have no ill effect on the rubber mold. We prefer to use white shellac, because it is less

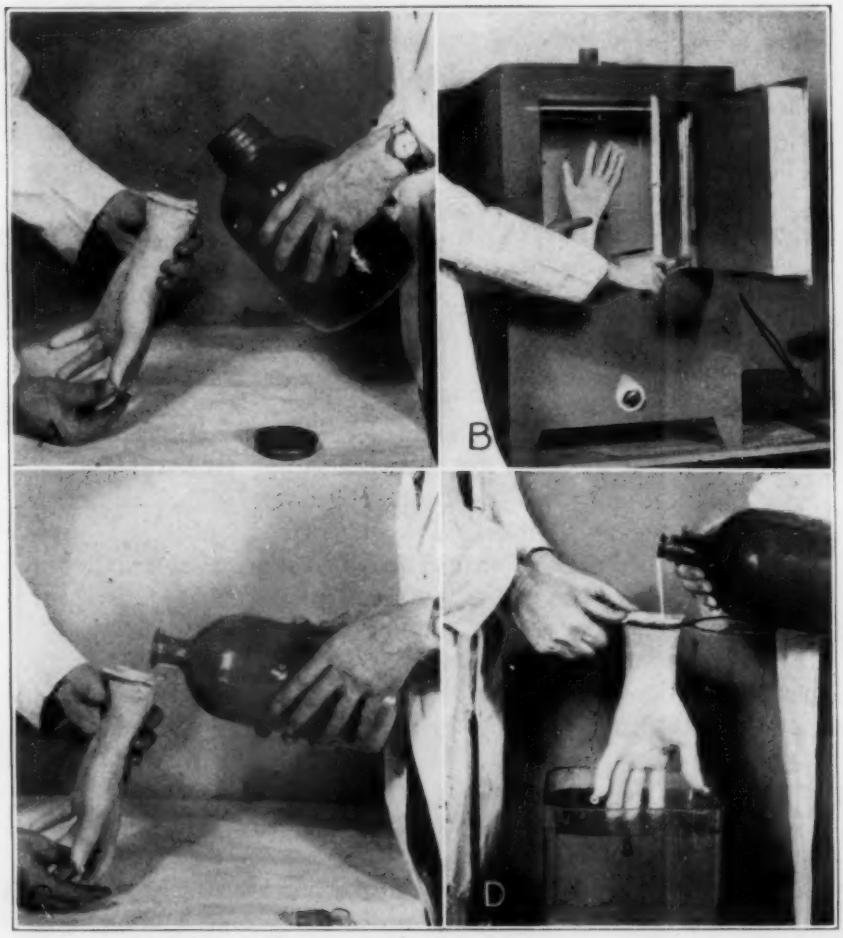

Fig. 4.—*A*, the dried rubber mold is treated with a clear, thin shellac separating medium. *B*, it is then hung in the oven upside down to dry. *C*, after drying, it is treated with a coagulating agent. This is allowed to dry thoroughly in the oven before the latex is poured. *D*, the mold is placed on a heavy wire hanger and held above the hot water. As the latex is poured, the mold is allowed to sink into the water. In some cases, it is preferable to strain the latex as it enters the mold.

expensive than lacquer. Also, the solvent for shellac is alcohol, which is less offensive in odor than acetone, amyl acetate and other organic solvents for lacquer.

If dry shellac is used, it must be cut with twenty times its volume of alcohol. A small amount of sodium borate should be added to the mixture to hasten the dissolving of the dry shellac into the alcohol, a process which might otherwise take days.

It is more convenient to purchase the white shellac as a 4 or 6 pound (1.8 or 2.7 Kg.) cut of liquid shellac. Then the volume is doubled or tripled by simply adding more alcohol. A jar of this mixture is allowed to stand until an opaque, light sediment sinks to the bottom. The clear, transparent liquid that rises to the top is carefully poured or siphoned off. This is the mixture most suitable as a separating medium. It is simply poured from a big-mouthed jar into the mold. The mold is then inverted, and the excess shellac is poured back into the bottle. The mold is then hung by the rings on the fingers to drain back into the big mouth bottle. Drying can be materially hastened by placing the mold in an oven at about 90 C. If a coating of shellac has any tendency to crack, a small quantity of castor oil should be added to the liquid. However, if too much castor oil is used, the dried coat becomes sticky and is unsuitable. It may be removed with alcohol.

COAGULATING AGENTS

There are many coagulating agents for rubber. Where a thick deposit is necessary, it is advisable to use a concentrated latex. The thickness of the deposit is dependent on a number of factors, some of which can be controlled at the compounding stage. If unvulcanized latex is used, the simple addition of the vulcanizing ingredients increases the viscosity of the latex. The addition of 2 or 3 per cent of zinc oxide in particular has been found to have an appreciable thickening effect on latex. If more than 5 per cent is added, a complete coagulation of the entire mixture may result. Some soluble metallic salts, such as calcium sulfate in small quantities (0.3 per cent of the dry rubber content), cause a slight thickening and render the latex sensitive to local heating. By this addition or pretreating of the latex mix, a firm, thick coagulum may be built up when the mixture comes in contact with hot surfaces. Salts of magnesium and zinc also serve for this purpose.

Other coagulants commonly employed are acetic acid, formic acid, calcium chloride, acetate, nitrate or formate, zinc chloride and ammonium acetate in water. Acetone or alcohol solutions are also used, depending on the molding material and the conditions under which it is desired to effect a coagulation. Methyl alcohol has been of value because of its readily wetting properties. Two or more coagulants have been used together, as, for example, calcium chloride (2.5 per cent) in equal parts of methyl alcohol and water. In fact, we have found calcium chloride and acetic acid among the best coagulants for prosthetic work, according to the problems to be solved. The coagulating agent may be painted

or sprayed on the surface of a mold, or it may be poured into a closed mold and drained out. It may or may not be dried on the form. A coagulant should be chosen and applied in such a manner that the rubber

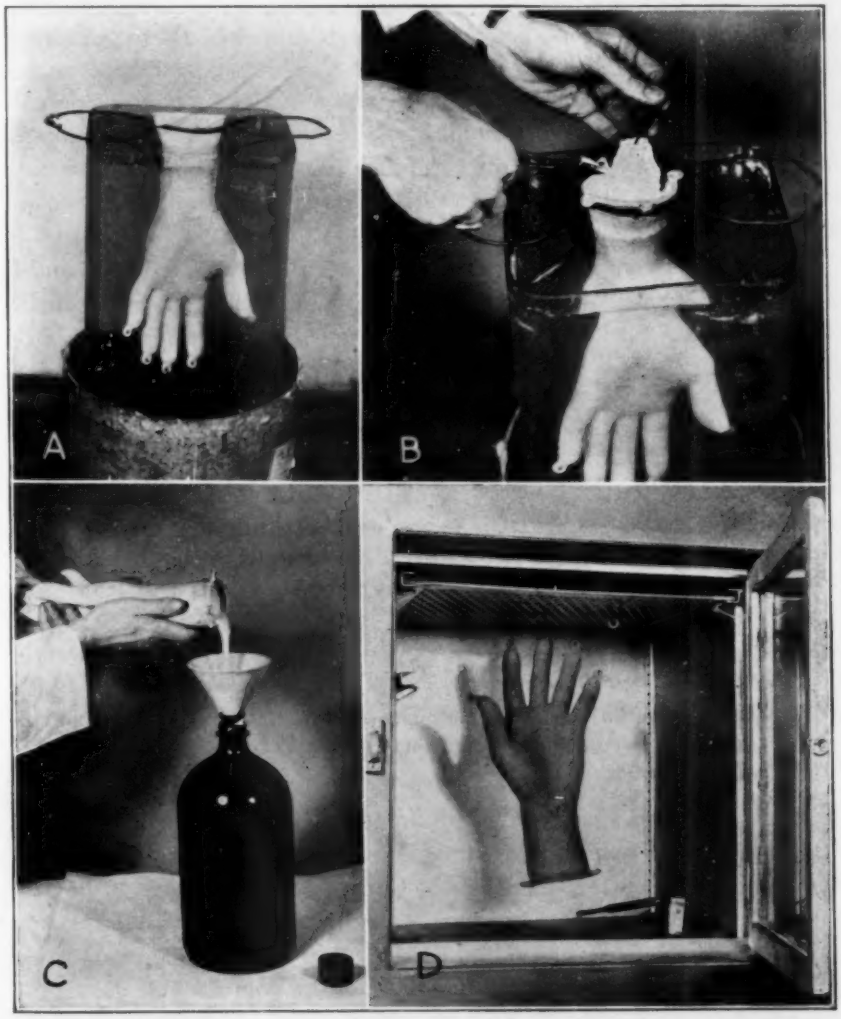

Fig. 5.—*A*, the mold is allowed to remain in the hot water until a coagulum of sufficient thickness is deposited on the surfaces of the mold. *B*, a coagulum deposit also builds up over the entrance to the mold. This is cut away with sharp scissors and removed. *C*, the excess latex is then poured back into the original container. *D*, the hand is then placed in the oven at about 90 C. for an hour or more for drying and curing. It dries better if it is hung from the wrist end after complete drainage has taken place and the drying has begun.

will be coagulated immediately, so that there will be little tendency for the latex to flow or cause "sags." Sags may be the result of two thin coagulated surfaces of latex between which is a deposit of uncoagulated

latex. In other words, they may be produced by coagulation of one layer over another in the same mold, a practice which is not always recommended. It is always best to try to build up a desposit of sufficient thickness in one pouring. After the deposit is made, it must be dried. In the case of prosthetic rubber hands, a melted microcrystalline wax may be poured into the hollow hand before it is removed from the mold, to prevent shrinkage of the rubber and to make the hand of practical use. In such a case an unvulcanized latex formula may be used, because the hot wax will vulcanize the thin deposit of rubber. However, if the hand is to be enlarged by swelling, the wax is left out, but vulcanized latex must be employed.

To build up a coagulum deposit for prosthetic hands, we have obtained excellent results with a mixture of magnesium sulfate and ammonium chloride, which is held in place with casein. The following formula is prepared:

Part A	
Casein	3¼ ounces (97.5 Gm.)
Sodium borate	½ ounce (15 Gm.)
Beta naphthol	50 grains (3.2 Gm.)
Hot water (212 F.)	16 ounces (473 cc.)

The casein is soaked in the hot water for ten minutes. Then the sodium borate is added, and the mixture is stirred or shaken. The beta naphthol is then added while the mixture is being stirred.

Part B	
Ammonium chloride	7 ounces (210 Gm.)
Magnesium sulfate	12 ounces (340 Gm.)
Hot water	28 ounces (828 cc.)

The ingredients in part B are mixed together until they are in complete solution. If necessary more water may be added. Part B is then added to part A while the mixture is being stirred.

The coagulating agent is applied after the separating medium is dry. This is done by pouring the mixture into the mold, draining it out and then allowing the surface of the mold to dry. This produces a cast of sufficient thickness to be of practical value.

The casein holds the metallic salts in place so that they can have their action on the rubber latex when it comes in contact with the mold.

THE LATEX FORMULA

The latex formula which we have found to be the most suited for prostheses is composed of:

Vultex H222	90 parts by volume
Vultex H222 part B	10 parts by volume

However, this can be varied to suit specific conditions or can be compounded differently with the basic ingredients if so desired.[2]

2. Clarke, C. D.: The Rubber Prosthesis, in Facial and Body Prosthesis. St. Louis, C. V. Mosby Company, 1945.

To facilitate an even and undistorted deposit of rubber on the mold, a container of hot water near its boiling point is prepared. A wire holder is then fixed around the open end of the hand mold. The mold is held over the container, and as the latex is poured into the mold it is allowed to sink into the hot water. This prevents distortion from ballooning. The wire retainer will eventually come to rest on the sides of the container. The hot water speeds the action of the coagulating agent on the latex, which should remain in the mold for from one-half hour to one full hour, depending on the thickness of the deposit that is desired.

During this time a skin, or film, of rubber will be built up over the opening of the mold. This must be removed with a pair of sharp, pointed scissors, the cutting being done about ¼ inch (0.64 cm.) toward the center of the opening away from the surface of the mold. The mold is then removed from the hot water, and the excess latex is poured back into the container. The mold is suspended over the container until it ceases to drain. This takes about ten minutes.

If one looks into the mold at this point, one will find there a coagulum deposit of rubber about ⅛ inch (0.32 cm.) in thickness. This is still wet and easily broken, so no attempt should be made at this point to remove the cast from the mold. Furthermore, the mold must now be handled with great care, because, should it be pressed or bent together, the inner surfaces of the cast will stick, and their separation becomes impossible without ruining the cast.

If the hand is not to be enlarged in the naphtha-liquid petrolatum mixture and is to be filled with wax for practical use, it is best to fill it at this point to prevent shrinkage. Also the hot wax has a toughening effect on the deposit of rubber. If this is not the case, both the mold and the cast are placed in the oven at 90 C. for about a half-hour to dry or cure the cast. During this time the cast shrinks rapidly from the mold. The excess water in the cast runs free and will gather in the mold if it is suspended with the hand down or will drip from the mold if it is suspended with the hand up. Nevertheless, the cast gains in strength to a point at which it can be pulled from the mold. Before this is attempted, the mold is allowed to cool and talc is dusted within to prevent the inner surfaces from sticking together. It will be noticed that the cast is decidedly smaller than the mold. This is caused by the uniform shrinkage of the cast from the nonabsorptive surfaces of the mold on coagulating and drying.

If the cast is not completely dry, it will be observed that it is much lighter in color than dried rubber, though rather opaque. This lightness can be preserved somewhat by soaking the hand immediately in the enlarging solution which is composed of:

Oil-free naphtha	8 parts by volume
Liquid petrolatum	2 parts by volume

A flat vessel of sufficient size to allow for considerable swelling should be used. The vessel should be large enough to eliminate the possibility of the cast's touching any two opposite sides at the same time. If this happens the swelling rubber, which has become weakened, will probably break. Crowding of more than one cast in the solution should also be

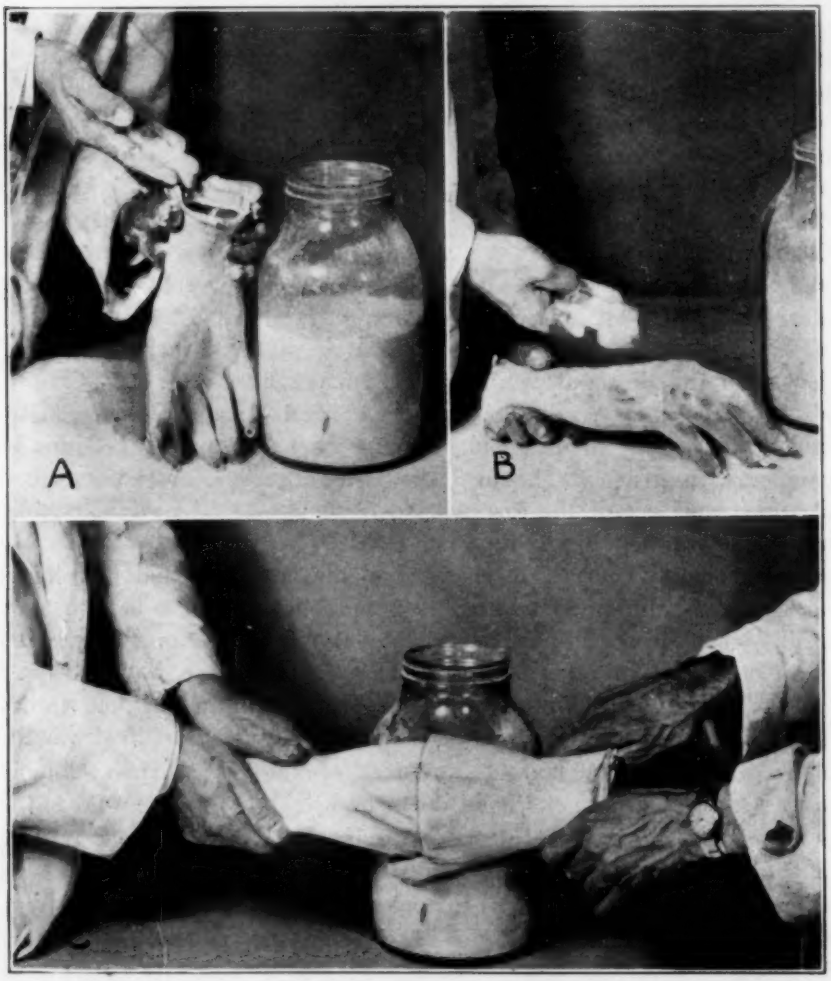

Fig. 6.—*A*, the inside of the prosthetic hand while still encased in the mold is treated with talc to prevent sticking when pressed together. It will be noticed at this stage that the hand has shrunk from the mold. *B*, the outside of the mold is also treated with talc so that the surfaces slide easily in the removal of the positive from the negative. *C*, the cast is then pulled from the mold.

avoided. These precautions are important because of the extreme friability of rubber on reaching greatly enlarged proportions.

On removal from the solution the volatile naphtha evaporates, leaving the cast impregnated with liquid petrolatum. On complete evapo-

ration of the naphtha, the rubber cast regains its strength for rough handling. When the cast has become uniformly enlarged, it may be removed carefully from the solution and placed on clean blotting paper to dry. After twenty-four hours, it should have shrunk to its proper proportions. As stated before, the content of liquid petrolatum in the enlarging solution can be varied to change the size of the resulting prosthetic hand. In this manner, prosthetic rubber hands of various sizes can be made from the same pattern or donor. They may then be used for remolding for additional rubber and resilient resin prostheses.

III. PROSTHETIC PLASTIC HANDS

The term "plastic" has come to have a variety of meanings. In fact, the meanings are so numerous that it becomes necessary to classify and

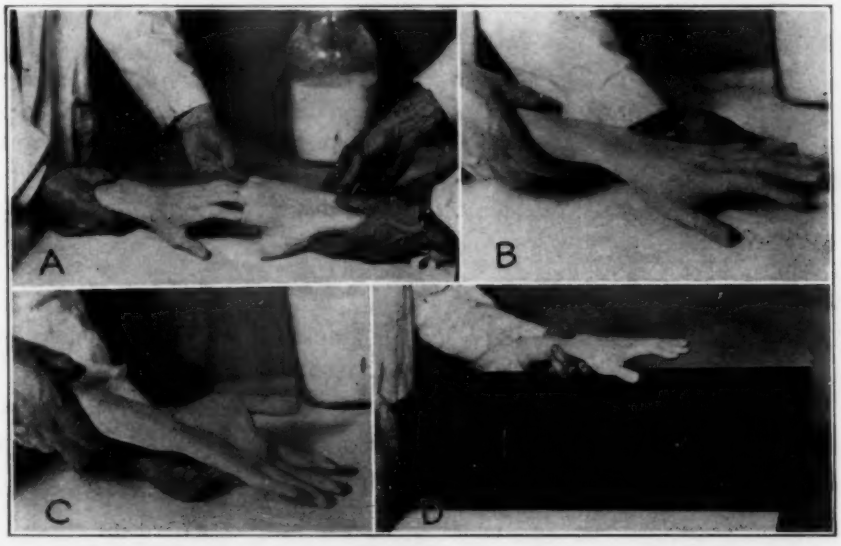

Fig. 7.—*A*, the hand finally emerges from the mold as the mold becomes inverted. *B*, the top surface of the rubber cast. It will be noticed that there are no seam lines. *C*, the palm side of the rubber cast. *D*, the prosthetic rubber hand is placed in the naphtha-liquid petrolatum solution for enlarging.

condense them into the confines of prosthetic uses. The Latin word *plasticus* was taken from the Greek *plastikos* and used by the French as *plassein* and the English as "plastic." Its first meaning was to "form" or "mold." From it are derived such words as "plaster," "plastecize," "plastodynamia" and many others.

Among the meanings of the word "plastic" are (1) giving form or fashion to a mass; formation; (2) causing or directing production or development; creative, as the "plastic" force of nature or "plastic" imagination; (3) capable of being molded or modeled, as clay or plaster; hence,

pliable; impressionable; (4) characterized by modeling; also, giving the effect of that which is modeled or sculptured, as "plastic" dancing; (5) in biology and surgery, that which is capable of undergoing metabolic transformation; formative; hence, pertaining to the growth, repair and transformation of tissues, as "plastic" lymph or "plastic" surgery; also, capable of structural adaptation to changing environment, as a "plastic" race or genus, and (6) in physics the capability of being deformed continuously and permanently in any direction, without rupture, under a stress exceeding the yield value.

In the plastic-manufacturing industry, the term has a variety of meanings. For example, a plastic can be the material used or the product produced. It can mean the extent of bendability, softness, hardness or fluidity of the material or the product. For example, a house paint is made more "plastic," or fluid, by thinning. The term "resilient" is also at times interchangeable with "plastic." However, it generally means the ability of rebounding or springing back into its previous form.

Basically, the plastic industry is a branch of chemistry. One simplified but broad version of the origin of plastics is that they are derived from "coal, air, lime and water." If four more basic natural substances are added—petroleum, cellulose, sulfur and salt—nearly all the commercial types of plastics can be accounted for. Naturally, these basic materials must be subjected to numerous chemical changes before the resulting plastic is produced.

The first step in the manufacture of plastics is the synthesis of a large group of simple chemicals, such as ammonia, acetylene and hydrochloric acid. From these, the various reactive ingredients are synthesized. The manner in which the latter ingredients are combined to produce the final product varies with the type of resin. In general, resins are either condensation type (i. e., phenolic resins), which result from the combination of dissimilar organic chemicals to produce new compounds, or polymerization resins (i. e., vinyl or acrylic), which result from a linking together of like molecules of the monomer to produce a resin of the same chemical nature but with different physical properties, called the polymer.

For the sake of convenience in a discussion of their preparation and properties, three categories of plastics are recognized. They are (1) thermosetting resins, (2) thermoplastic resins and (3) cellulose derivatives.

Thermosetting materials are those which harden when heat is applied. They must be formed relatively quickly in order to attain the desired shape before they become rigid. The five types of thermosetting resins are: (1) phenolic, (2) urea, (3) melamine, (4) silicon and (5) unsaturated polyester resins.

Thermoplastic materials are those which can be repeatedly softened by heat and hardened by cooling. No chemical reaction is involved in the shaping of thermoplastic resins. This group of resins is comprised essentially of seven types. They are: (1) nylon, (2) alkyd, (3) polyethylene, (4) styrene, (5) acrylic, (6) vinyl and (7) coumarone.

Cellulose derivatives in general are thermoplastic in their behavior toward heat. There are a variety of cellulose esters and ethers generally classified in the following five types: (1) nitrate, (2) acetate, (3) butyrate, (4) ethyl and (5) regenerated cellulose.

We have found that nearly all the thermosetting, thermoplastic and cellulose plastics in one form or another have been of use in prosthetic work. Furthermore, their possibilities of use in the future of this field are unlimited. New materials or different applications of old materials are suggesting themselves in such rapid succession that by the time this article comes off the press it will be "old stuff." Nevertheless, to our knowledge, it is the first published data on the making of seamless prosthetic hands in any plastic.

Although thermosetting resins may have a limited use in prosthesis, those which are presently available do not lend themselves well to this application; consequently, we shall be concerned purely with the thermoplastic resins. Of this type, the acrylic and vinyl resins are the most popular.

ACRYLIC RESINS

The best known member of the group of acrylic resins is methyl methacrylate, which has its main prosthetic application in the making of dentures and artificial eyes, because of its ready malleability, naturalness or similarity to human tissues when properly filled and colored. It is also relatively strong and is light in weight. Resins of this type are made from methyl and ethyl alcohols, acetone, hydrocyanic acid and similar chemicals. The reactions involved in the synthesis of the intermediate compounds are somewhat complicated.

VINYL RESINS

For the immediate purpose in mind, that of producing plastic prosthetic hands, the vinyl resins lend themselves admirably. For this reason, they will be described in more detail.

Vinyl derivatives are basically those produced by the substitution of one of the hydrogens in ethylene by some other group. Thus, the vinyl radical is $H_2C{=}CH{-}$. When a hydroxyl group replaces the hydrogen, the compound is vinyl alcohol. Analogously, the compound containing chlorine is vinyl chloride, and the compound containing an acetyl group is vinyl acetate. These are the three industrially significant vinyl derivatives. They are translucent, easily colored and readily plasticized

into soft, pliable, fleshlike resilient resins, which adapt themselves admirably to prosthetic work. A copolymer of vinyl chloride and vinyl acetate is also an important material for prosthetic use. In fact, it is the most important at the present in forming prosthetic hands. Derivatives known as polyvinyl acetals are produced by the reaction of aldehydes with polyvinyl alcohol; polyvinyl butyral made with butyraldehyde may be applied as a coating to fabrics. Another resin related to this group is polyvinylidene chloride, best known for its chemical inertness and its resistance to wear. The vinylidene radical is $H_2C{=}C<$, i. e., ethylene in which two hydrogens of one of the carbon atoms have been replaced by other elements or groups.

COUMARONE RESINS

The coumarone resins range from viscous liquids to high melting solids. Coumarone and indene obtained from coal tar are copolymerized in their production.

The great bulk of the products produced by the plastics manufacturers consist of molding powders. These powders are utilized commercially in the fabrication of all the familiar plastic items in every day use. However, this fabrication involves the use of elaborate equipment which compresses the heat-softened molding powder into molds under intense pressure. To withstand this pressure, the mold must be made of high quality, hardened steel and is consequently extremely expensive. This procedure is practical only when a great number of identical items are to be produced. Consequently, molding powders as such cannot be used for construction of prosthetic appliances.

While many attempts have been made to produce prosthetic hands in metal piece molds by hot injection and other forms of pressure, these have seldom been satisfactory. Pressure molding of such subjects invariably requires the use of cores, which in turn necessitates the making of piece molds or the complicated cere perdue or lost wax process of mold making. The use of piece molds results in casts having seam lines, which are painfully obvious. In attempts to remove these seam lines on prosthetic casts, details of the flesh are lost to such an extent that the cure is worse than the disease. The resiliency and elasticity of modern plastics make it possible to cast them both in pliable molds, such as one piece rubber molds and rigid one piece electrotyped molds. The latter is important for mass production of prosthetic hands and will be discussed more fully in another article.

In seeking plastic materials suitable for the small scale production of prosthetic appliances, we are restricted to those which may be fabricated under laboratory conditions, without utilizing high molding pressure or extremes of temperature. Of even greater importance is the necessity of using temporary molds of plaster, rubber or similar materials. Although

there are a number of liquid casting resins on the market, these are for the most part thermosetting resins of the phenolic type, which are rigid and do not have the other characteristics, such as color, which are required to simulate flesh. Consequently, of the broad field of plastics, we are limited to a few.

The acrylic resins, of which the most important is methyl methacrylate, may be plasticized by mixing the polymer, ground to powder form, with the liquid monomer. The resulting dough may be compressed into molds and heat cured to yield a homogeneous product. This process is used to produce dentures and artificial eyes. As the resulting material is rigid, it is not suitable for other types of prostheses. The liquid monomer acts as a temporary plasticizer and does not impart a permanent flexibility to the acrylic.

The most suitable plastics for our purposes are those of the vinyl type. These may be combined with certain plasticizing agents, which give them a lasting flexibility without sacrificing too much tensile strength. Chemically the molecules of the plasticizer become interposed between the molecules of the resin polymer and thus provide flexible links in the otherwise rigid polymer chain of molecules. As plasticizing agents, a great number of substances may be used, usually of an oily nature. Among the most efficient for the vinyl resins are dioctyl phthalate, dibutyl sebacate, triethylene glycol and derivatives of ricinoleic or phthalic acids. However, for best results, the plasticizer must be intimately combined with the resin as a part of the manufacturing process. There are several plasticized vinyl materials on the market which may be used. One such material called Plastisol, is manufactured by the Bakelite Corporation, primarily for electrical insulation; however, the clear or transparent grade resilient resin is suitable for prosthetic work. It consists of a suspension of vinylite resin in a suitable plasticizer and comes in the form of a semiliquid or paste. The viscosity may be lowered by the addition of more plasticizer (this also increases the flexibility in the cured product at the expense of tensile strength). On heating to approximately 130 C. the material cures by fusion of the ingredients. With proper filling and coloring, the appearance can be made similar to flesh.

Another product that has proved successful is sold under the trade name of Elastomer number 105 by the Electro-Technical Products Co. (Nutley, N. J.). This material, which is shipped in liquid form, has considerable elasticity, resembling rubber in this respect. It has more strength than Plastisol and can be cured at lower temperatures. Elastomer is a viscous material with a 100 per cent solid content, which will cure and polymerize by the simple application of heat without pressure. It does not shrink or expand materially during the curing process and will take the finest details of the mold. While it resembles rubber in many characteristics, it is unusual in its resistence to most

solvents, including aromatic hydrocarbons, oils, acids, alkalis and water. It does not oxidize and harden on aging. It retains its flexibility even at extremely low temperatures, and it does not sustain a flame. It can be cured at lower temperatures than most plastics, which is advantageous when the fact is considered that rubber molds are used to obtain the plastic hands.

Its first drawback was that it was dark yellow on curing. However, by mixing with Plastisol and desensitizing pigments, this yellow color was overcome, and fleshlike prostheses of practical color and strength were obtained. Since these early experiments, the manufacturer has been so kind as to furnish us with a material which is lighter in color on curing. Elastomer is excellent for use in prosthetic hands, which must be stretched over mechanical devices to gain movement of the extremity.

PLASTICIZERS AND THINNERS

Plastisol, or the liquid form of polyvinyl plastics, is really a suspension of the vinylite powder in the proper plasticizers and thinning agents. This physical suspension does not become a homogeneous chemical mixture until heat is applied. While thinning agents may be classified as plasticizers for the purpose of this text, we wish to make a differentiation. We consider a thinning agent to be a volatile liquid which serves only to increase the fluidity of the ordinarily sluggishly flowing plastic, to facilitate ease in molding. In the curing process, it is completely volatilized, leaving no plastic effect on the product. A plasticizer may be considered an agent which plasticizes or softens the resulting cured plastic. In plasticizing with some plasticizers, the resulting product may lose in strength. In the making of prosthetic hands, it is necessary to use plasticizers which do not reduce the strength of the product beyond a certain point. In other words, in research along this line there must be a constant balancing of one quality against another at some cost to produce the final result. For example, sometimes strength must be sacrificed to a certain point to produce softness and vice versa.

The commercially prepared materials are apparently similar in nature to the materials mentioned previously but sold already filled and pigmented for prosthetic purposes. Flexiderm is marketed by the Nelson Kramer Corporation. Skin-tex [3] and Di-Cor [4] utilize a powder-liquid combination. The directions given by the Vernon Benshoff Co. recommend that their material be mixed to a doughy consistency and then packed into plaster or synthetic stone molds. This method is suitable for most ear and nose prostheses but is not suitable for hand prostheses made in one piece rubber molds. However, we have been able to plasticize their powder into a suitable liquid for pouring into one piece

3. H. D. Justi and Son, Inc., Philadelphia.
4. Vernon-Benshoff Co., Pittsburgh.

rubber and one piece metal molds. Furthermore, we found it to be compatible with Plastisol and Elastomer. By mixing various materials we were able to obtain any plasticity desired at no great loss to strength.

FILLERS AND COLORING AGENTS

Both Plastisol and Elastomer require some compounding before they are used. Indeed this is also necessary with Flexiderm, Di-Cor and similar products if the correct tone of the skin is to be duplicated. On curing, the raw or natural plastics Plastisol and Elastomer are almost transparent and slightly yellow. To these liquid materials we add a filler in the form of talc, zinc oxide, titanium dioxide, calcium carbonate or one of any number of other materials to reduce the translucency. The properly filled and colored materials on curing should produce a prosthesis closely resembling flesh in visual detail, translucency and color and should be the same to the touch. Good texture is obtained from properly made molds. The natural feel is obtained by good plasticizing. The correct translucency is achieved by the use of the suitable filler in the right amount. The proper color is obtained by the incorporation of pigments and dyes to produce a basic monochrome tint. For pigmentation cadmium red as a base color for fair skin and alizarin crimson for more swarthy complexions are recommended. Yellow is seldom used because yellowness may be achieved by slightly increasing the curing time.

The final toning (coloring) of the individual parts of the hand such as veins, knuckles and finger nails is bled or diffused into the plastic to such an extent that it will not be removed by washing or scrubbing. The basic coloring agents can be in the form of dry pigment, artist's oil color or oil-soluble dyes to resemble the basic flesh tones. Oil-soluble dyes in volatile solvents are used exclusively in the final toning or coloring. Of course, they should be chosen for permanency.

MAKING THE PLASTIC CAST

After the rubber mold is completed and removed from the donor, it is washed, while still reversed, with soap and warm water. Feather edges will be found in the mold where the rubber ran under the finger nails. It is best to cut them off with a pair of scissors. The mold is then turned back to its normal position by pushing the eraser end of a pencil into the fingers. The mold is allowed to dry thoroughly for a few minutes in an oven at about 75 C. It is now ready to receive the liquid plastic.

The previously prepared plastic should be kept in closed, large-mouthed bottles, each bottle representing a slight difference in basic color. To the neck of each bottle should be tied a cured sample of the mix within the bottle. This is purely for matching against the patient's skin in choosing the proper mixture.

The mold is held beneath the bottle containing the plastic, and a small amount of the compound is poured into it. This is seldom more than one third of its content. The mold is then grasped between the palms of both hands and rolled and rotated in massaging the mixture

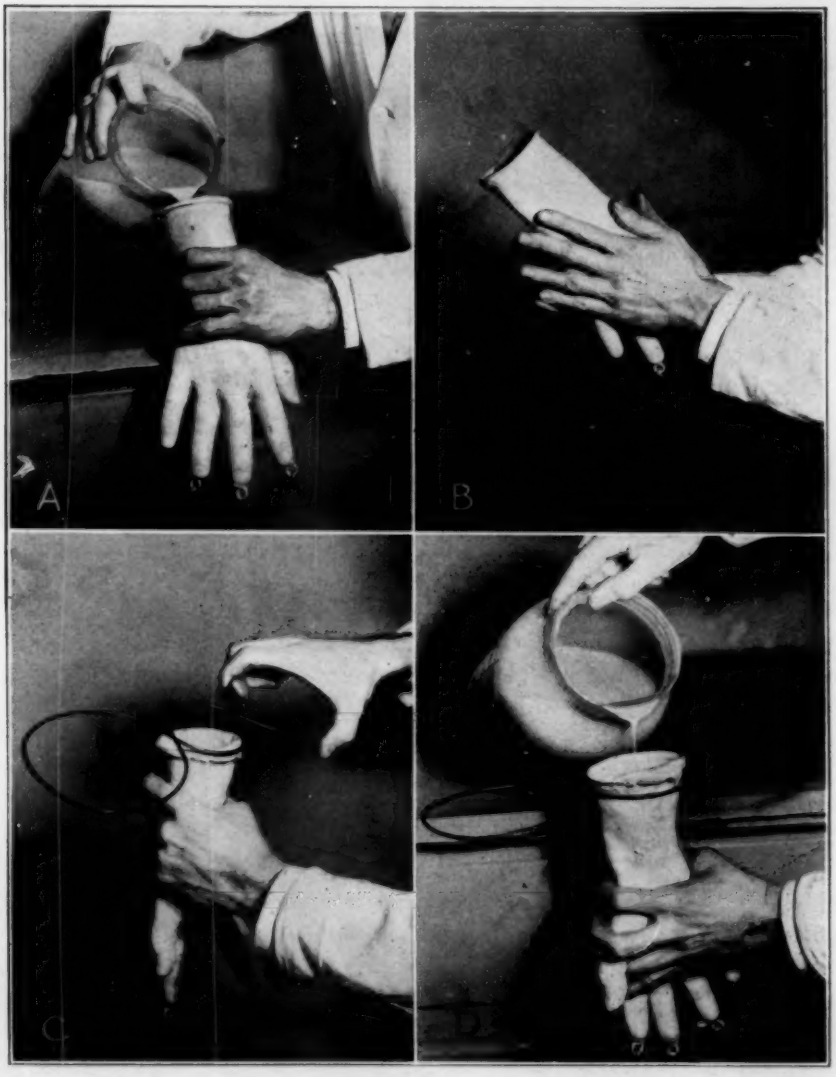

Fig. 8.—*A*, the mold is poured half full of plastic. *B*, the mold is massaged to eliminate air bubbles. *C*, the metal holder is placed around the open end of the mold. *D*, the mold is filled with plastic.

over the entire inner surface. This is done to break the air bubbles that may form on the surfaces or within the mixture. The fingers should each receive individual attention because they are more likely to collect air bubbles and air pockets than the palms.

Before the mold is filled, a large, straight-edged vessel of water is placed on the stove and started to boil. The water should come to

Fig. 9.—*A*, the mold about to be lowered into boiling water. *B*, filled mold is clocked in the boiling water to build up a deposit. *C*, surplus plastic is poured back into the jar. *D*, the mold is drained for three minutes.

within ½ inch (1.2 cm.) of the top of the container. Once it boils vigorously, the heat is turned down until only a slight movement takes

place. This water will be used to build up an even deposit of the plastic on the inner surfaces of the mold.

A metal holder, as seen in the illustrations, is also previously prepared. Such metal holders can be made from heavy, soft, iron wire. In fact, discarded wire suit hangers serve admirably for this purpose

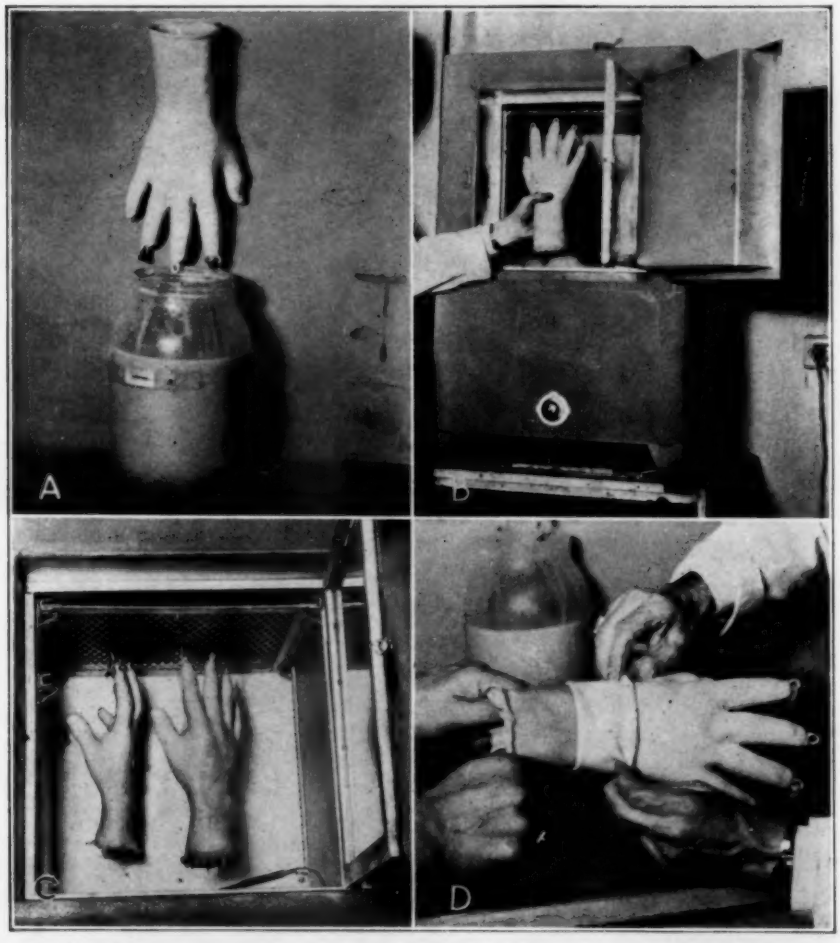

Fig. 10.—*A*, the mold is inverted and hung for two minutes, allowing the plastic to return to the finger tips. *B*, the mold is placed in the curing oven. *C*, the molds are cooled in the oven before being removed. *D*, the starting of the removal of the mold from the cast.

when properly reshaped. The metal holder is slipped over the wrist part of the mold. Then the mold is filled with the plastic to within ¼ inch (1.9 cm.) of the top.

The filled mold is then lowered into the boiling water until the holder comes to rest on the edges of the vessel. The moment the mold is placed

in the water notice is taken of the time, which is kept in seconds. The longer the mold remains in the boiling water, the thicker will be the deposit. This thickness of deposit also depends on the viscosity of the plastic. Thin or plasticized mixtures build up deposits more slowly. Thick or viscous mixtures build up deposits rapidly and have a tendency to become solid within the fingers. If the mixture is correct in viscosity, a uniform thickness of $\frac{3}{32}$ inch (0.24 cm.) will be built up throughout, including the fingers, in forty-five seconds.

The mold is now removed from the boiling water and held with a dry towel to prevent burning the hands. The undeposited plastic is

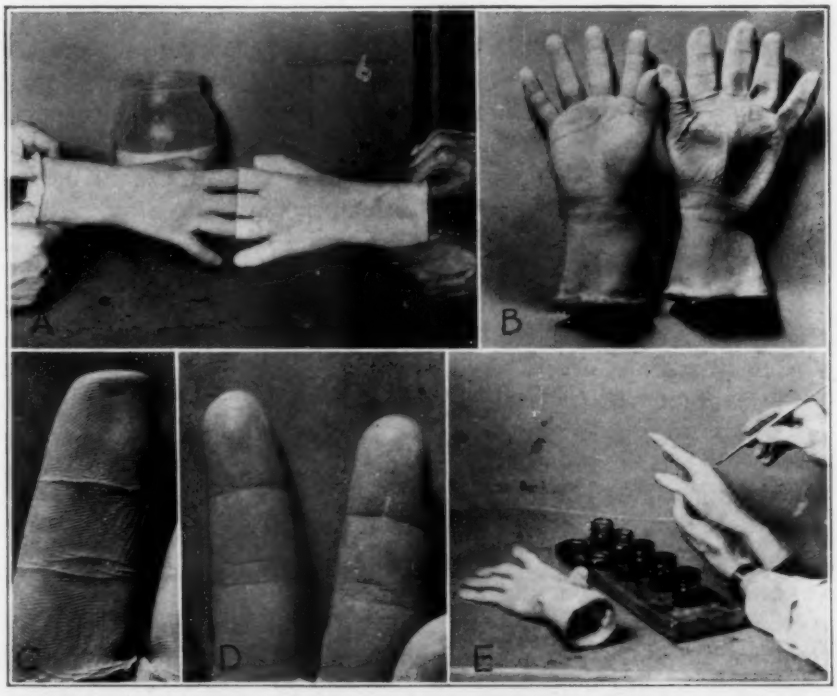

Fig. 11.—*A*, further emergence of the cast. *B*, the cast and reversed mold immediately after removal. *C*, enlarged detail on the finger of the reversed mold. *D*, surface of the fingers of the cast. *E*, the finished hand is painted.

poured back into the original container, care being taken to prevent the mold from collapsing. Should this happen, thin areas may appear where the inner surfaces of the cast touched. The mold can be hung by one of the rings on a finger and allowed to drain for about three minutes. The position is then reversed, the mold being hung by the wrist end for about two minutes. The purpose of this maneuver is to allow the sluggishly flowing plastic to continue to build up an even deposit and to prevent a collection of the mixture into one place. Fur-

thermore, this changing of position also increases the deposit on raised edges within the mold, which have a tendency to run thin.

As the mold is moved to the curing oven the position is reversed again, and it is hung in the oven by the rings on the tips of the index and ring fingers. The cast within the mold is cured for fifteen minutes at 100 C. To the average worker who is accustomed to curing plastics in plaster of paris, synthetic stone and metal molds, this may seem to be a rather short time for curing. This results largely from the thinness of the rubber mold, the plastic deposit and the quickness of heat penetration. Temperatures and times in excess of those given should be avoided, since they cause distortion and rapid deterioration of the mold, as well as darkening, drying, crazing and cracking of the cast. If Plastisol is used, it should not be removed from the oven until it has cooled to room temperature, as this material is easily cracked if it is bent while hot. Molds containing Elastomer should be removed from the oven while hot and repoured first on a slant to prevent the trapping of air. On cooling of the mold, the surplus is poured back into the jar and the mold drained for three minutes. It is then reversed and hung by the wrist for two minutes. The mold is now replaced in the oven and hung by the rings on the fingers and cured again for fifteen minutes at 100 C. In other words, the same process is repeated in an effort to build up thick, uniform deposits. In fact, it may be repeated three or four times if desired; however, two times generally suffices for the average cast. The last baking can be done for twenty minutes at 100 C. to insure thorough curing.

After the mold and cast have completely cooled, the mold is dusted with talc to allow it to slip easily or invert on itself in removal of the cast from the mold. One person then grasps the cast while another grasps the mold, and the two are separated.

After removal from the mold additional sheen or lifelike appearance may be obtained by giving the cast a thin coat of castor oil and rebaking it alone at 70 C. for fifteen minuutes. This not only gives it a desirable sheen but increases its pliability or lifelike feel. We have also found that the cast can be materially strengthened by additional curing, effected by placing it in glycerin which has been brought to a temperature of 130 C. and allowing it to remain there until completely cooled. Finally, the hand is colored with small brushes and oil-soluble dyes, which bleed into the plastic, thereby becoming permanently incorporated into it. This process is described in detail in chapter IX of "Facial and Body Prosthesis" [5] and will not be considered further here. In this chapter, the painting of rubber protheses is discussed. The same technics and dyes are used for plastic prostheses.

5. Clarke, C. D.: Facial and Body Prosthesis, St. Louis, C. V. Mosby Company, 1945.

THORACICOABDOMINAL APPROACH TO UPPER PORTION OF ABDOMEN AND UPPER POLE OF KIDNEY

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THE DIAPHRAGM has always acted as a barrier to the progress of upper abdominal surgery. As a result the structures in the region of the diaphragm, such as the lower portion of the esophagus and the cardiac end of the stomach, have been neglected surgically. This is partly due to the fact that the chest itself was not opened up to surgeons until comparatively recently. However, even after open thoracic operations were made safe, the diaphragm remained a barrier, so that surgeons argued the advantages of the transthoracic versus the abdominal approach to diaphragmatic hernia. Obviously, if no harm would come from traversing the diaphragm, it would be of tremendous advantage to be able to repair a diaphragmatic hernia with both the abdominal and the thoracic cavity open. The same applies to lesions of the lower part of the esophagus. In most of these lesions the site of the primary pathologic process is where the esophagus passes through the diaphragm. Here, again, the discussion has centered around the question whether it is better to approach the lesion from below or from above the diaphragm. Again, the ideal method is to dissect the diaphragm away from the esophagus and approach the esophagus at the site of the lesion. Lesions of the cardiac end of the stomach have been treated by total abdominal gastrectomy. This operation requires an unnecessarily wide resection below the lesion, but the resection stops at the diaphragm and so falls short of a complete resection above the lesion, where wide resection is most needed. If the diaphragm were opened, the shortcomings of total gastrectomy could be avoided. The spleen and the upper pole of the kidney are other organs which border on the diaphragm and have often presented difficult and dangerous technical problems because of the limitations imposed by the diaphragm.

In this paper I shall discuss the technical feasibility of traversing the diaphragm; I shall present an operative technic and show, with illustrative cases, how such an approach has given a better understanding of some of the lesions encountered in the region of the diaphragm.

In 1941 I first had occasion to open the diaphragm and perform a combined thoracic and abdominal operation. The patient had a huge

Read at the Fifty-Fourth Annual Meeting of the Western Surgical Association, Memphis, Tenn., Dec. 7, 1946.

dumb-bell-shaped chondrosarcoma [1] arising from the seventh and eighth costal cartilages on the right side and traversing the diaphragm, approximately half the huge tumor being in the chest and half in the abdomen. To remove this tumor, it was necessary to split the diaphragm and remove part of the costal arch. I have recently reexamined this patient, five and a half years later, and found that she has had no difficulties resulting from this operative procedure.

The same year I had a patient with a traumatic diaphragmatic hernia. I debated whether to use an abdominal approach, for he was having symptoms of obstruction, or whether to use the more favorable thoracic approach. I used the thoracic approach, but on opening the chest I found that the diaphragm was split from the costal attachment through the esophageal hiatus, so that I really had a combined thoracic and abdominal approach. I found it easy to inspect and replace the abdominal organs. I have also seen this patient, five years later, and he has had no difficulties resulting from the operation.

In 1942, while I was in the Army, Dr. Rubin Lewis, of Philadelphia, and I dissected a cadaver. We discussed the possibilities of approaching the upper part of the abdomen through the chest and worked out on the cadaver what we thought was the best incision. Soon after that I went overseas and had no opportunity to use the incision. However, since I have returned, I have employed this incision in a number of cases and have found it satisfactory. I shall present cases illustrating its usefulness.

TECHNIC OF OPERATION

The patient is placed on the operating table in a true lateral position, with the left side up. Endotracheal anesthesia induced with a nitrous oxide–oxygen–ether mixture is used. The incision is made over the ninth rib and extended from the angle of the rib to the anterior margin of the costal arch. The ninth rib, together with its costal cartilage, is removed subperiosteally and the thorax opened through the periosteal bed. The thoracic cavity is then explored, and any adhesions to the diaphragmatic pleura are divided. It is well at this time to divide the pulmonary ligament and crush the phrenic nerve. The costal arch is then divided and the edge of the diaphragm picked up to start the incision through the diaphragm. The diaphragm is then split from its costal edge to the esophageal hiatus. Rib spreaders are then inserted, which open the incision sufficiently to give adequate exposure to the structures from the pylorus of the stomach to the arch of the aorta. It is necessary to divide the peritoneal reflection from the cardia of the stomach and the lower end of the esophagus. At the completion of the operation the diaphragm is closed with two rows of interrupted cotton or silk sutures, and the thoracic incision is closed in the usual manner with interrupted cotton sutures. In most cases it is not necessary to use suction drainage, but in cases in which an anastomosis has been made between the stomach and the esophagus I think it is advisable. I have routinely used an oxygen tent for twenty-

1. Harper, F. R.: Huge Chondrosarcoma Arising from the Chest Wall and Extending into the Thorax and Abdomen, J. Thoracic Surg. **11**:446, 1942.

four to forty-eight hours after operation. After that the patients are allowed to get out of bed, as I think early ambulation is advisable. None of them has had any postoperative difficulties.

Humphreys [2] described an abdominothoracic approach for carcinoma of the esophagus and the cardiac end of the stomach. He makes an abdominal incision and, after exploring the abdomen, turns the patient over and extends his incision into the chest through the eighth intercostal space. I prefer the incision I have described in that it eliminates turning the patient in the middle of the operation and avoids weakening the abdominal wall by the additional abdominal incision. Allison,[3] an English surgeon, recently described an approach very similar to the one I have been using. Sweet [4] used a thoracic approach for carcinoma of the esophagus and cardia of the stomach. He stated that when the exposure was not adequate he did not hesitate to divide the costal arch.

CARCINOMA OF THE CARDIA AND ESOPHAGUS

The most important lesion requiring adequate exposure of both the stomach and the esophagus is carcinoma of the cardiac end of the stomach and the lower end of the esophagus. An incision such as I have described allows for adequate resection of both the stomach and the esophagus and makes the anastomosis easier because it can be done under direct vision. It is easier to control bleeding, and the split diaphragm can be sutured to the stomach at the desired level.

CASE 1.—Esophagogastrectomy for carcinoma of the cardiac end of the stomach: A white man aged 46 had noticed difficulty in swallowing for eight months prior to admission. He complained of increasing weakness and loss of approximately 30 pounds (13.6 Kg.) of weight. After admission to the hospital he began to have tarry stools. Esophagoscopic examination was made, but the esophagoscope could not be passed into the stomach because of the lesion. Biopsy revealed adenocarcinoma. Through a thoracicoabdominal incision the spleen was removed and the upper third of the stomach resected, together with the lower 2 inches (5 cm.) of the esophagus. The cut end of the remaining portion of the stomach was closed. An elliptic opening was made in the wall of the stomach into which the esophagus was anastomosed. The diaphragm was sutured to the stomach just beyond the anastomosis. The patient made an uneventful recovery and three months after discharge from the hospital was eating solid food without difficulty.

I feel that this operation has distinct advantages over total gastrectomy in that the resection was more complete and that by leaving two

2. Humphreys, G. H., II: An Approach to Resection of the Esophagus and Gastric Cardia, Ann. Surg. **124**:288, 1946.

3. Allison, P. R.: Peptic Ulcer of the Esophagus, J. Thoracic Surg. **15**: 308, 1946.

4. Sweet, R. H.: Transthoracic Gastrectomy and Esophagectomy for Carcinoma of the Stomach and Esophagus, in Bailey, C. P.: Diagnosis and Management of the Thoracic Patient, Philadelphia, J. B. Lippincott Company, 1945.

thirds of the stomach the operation was more physiologic than if an esophagojejunostomy had been performed.

Case 2.—Carcinoma of the stomach extending into the esophagus: A white man aged 58 had complained of burning pain in the epigastrium and difficulty in swallowing for about one year. He also had frequent coughing spells after meals. He had had occasional tarry stools and had lost 20 pounds (9.1 Kg.) in weight. Roentgenograms showed extensive deformity of the outlines of the lower portion of the esophagus and the cardia. Through a thoracicoabdominal incision the upper third of the stomach and the lower 5 inches (12 cm.) of the esophagus were removed, after removal of the spleen. The cut end of the stomach was

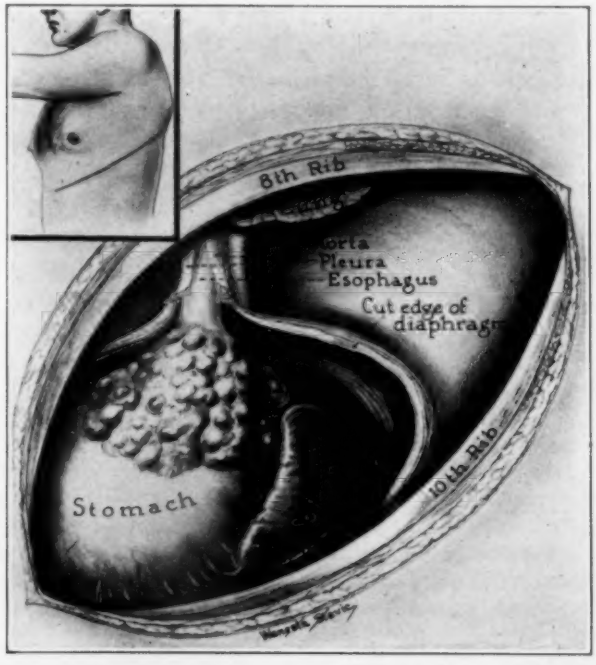

Fig. 1.—Artist's drawing illustrating the exposure obtained from the thoracico-abdominal approach.

sutured and an elliptic incision made in the wall of the stomach into which the esophagus was sutured. The diaphragm was sutured to the stomach below the anastomosis. The patient was last seen seven months after his operation. His only complaint was slight difficulty in swallowing certain coarse foods.

DIAPHRAGMATIC HERNIA WITH OBSTRUCTION

In some cases a large hiatal hernia of the diaphragm associated with vomiting it would seem desirable to explore the abdominal organs. Yet the abdominal approach to these hernias seems much more difficult and less advantageous than the thoracic approach. With a thoracico-abdominal approach the advantages of the abdominal and the thoracic approach are combined.

CASE 3.—A white woman aged 39 for the past three years had had attacks of severe abdominal pain while lying down. These attacks of pain were accompanied with vomiting of undigested food. She obtained some relief by elevating the head of the bed. On several occasions she had persistent cramplike pains, which extended under the sternum toward her throat. On these occasions the pain lasted two to four days and then left suddenly. Operation was performed through a thoracicoabdominal incision. On opening the chest, about one third of the stomach was observed to be herniated through the diaphragm. The diaphragm was split to the hernial ring and the hernia sac dissected out. The stomach was then replaced in the abdomen and the abdomen explored. The cardiac end of the stomach was loosely sutured to the under surface of the diaphragm and the dia-

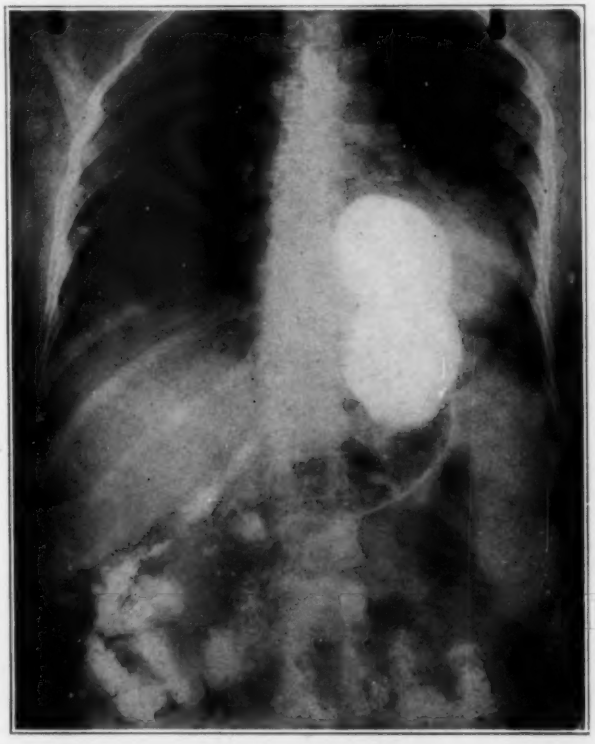

Fig. 2.—Roentgenogram showing large diaphragmatic hernia.

phragm closed around the esophagus. Since the operation there has been no return of the original symptoms.

CASE 4.—A white woman aged 63 had complained of pain in the upper part of the abdomen and the lower part of the chest for ten years. The pain came on after eating solid food, and repeated attacks of vomiting had accompanied the pain. Operation was performed through a thoracicoabdominal incision. On opening the chest, approximately one half of the stomach was observed to be herniated through the diaphragm into the chest. Operation was carried out in a manner similar to that in the previous case. Three weeks after the operation she had a slight stroke, from which she recovered rapidly. Her abdominal symptoms have disappeared.

DIAPHRAGMATIC HERNIA ASSOCIATED WITH PEPTIC ULCER OF THE ESOPHAGUS

CASE 5.—A white woman aged 64 complained of pain in the upper part of the abdomen of four years' duration. She described the pain as coming on one-half hour after meals and at night. It was frequently associated with regurgitation of gastric contents, which was so frequent as to cause severe glossitis. She had also had frequent tarry stools, as well as occasional vomiting of blood for four years. At the time I first saw her, she had had severe hematemesis, and, although she had had four blood transfusions during the week, her blood pressure was

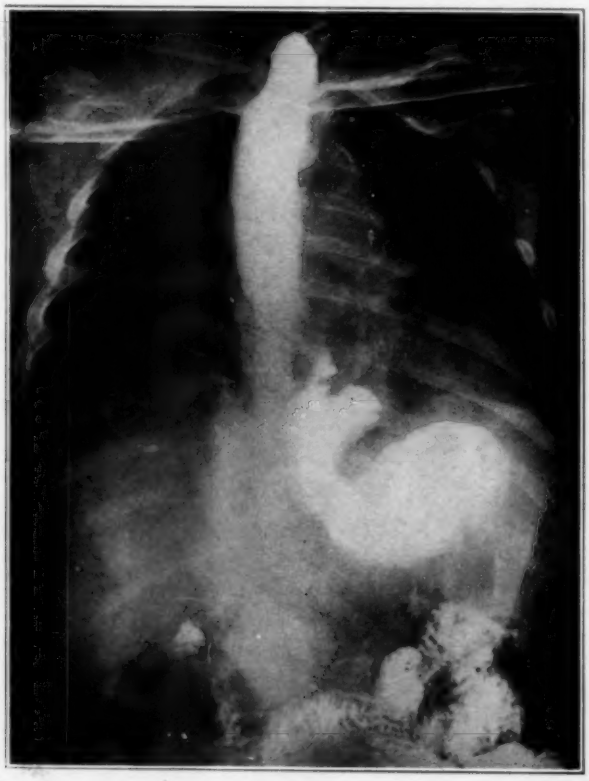

Fig. 3.—Roentgenogram showing hiatal hernia of the diaphragm associated with peptic ulcer of the esophagus. Note the inflammatory constriction of the lower end of the esophagus with dilatation above.

only 80 systolic and 40 diastolic. Her red blood cell count was under 3,000,000. Her weight had decreased from 200 pounds to 120 pounds (90.7 to 54.4 Kg.) in four years. She was placed on a regimen of 15 minims (1 cc.) of tincture of belladonna fifteen minutes before eating and 1 fluid drachm (4 cc.) of liquid petrolatum just before eating and was given feedings every two hours while awake. The bleeding stopped, and she improved considerably during the next two months. Roentgenograms showed a hiatal hernia of the diaphragm with narrowing and ulceration of the lower end of the esophagus. Esophagoscopic examination showed ulceration of the lower end of the esophagus. Biopsy revealed only inflammatory

tissue. Operation was performed, using a thoracicoabdominal incision. On entering the chest, extensive adhesions between the lower lobe of the left lung and the diaphragm were observed. About one fourth of the stomach was herniated into the chest. On splitting the diaphragm, considerable inflammation was seen around the hernial ring, and the hernial sac was adherent to the surrounding structures and the esophagus. The esophagus itself was thick walled and inflamed. The esophagus was carefully dissected free and the stomach replaced in the abdomen. The abdomen was explored and the diaphragm then sutured around the esophagus after being first anchored to the cardia of the stomach. Since the operation the patient has had no return of her original symptoms or bleeding.

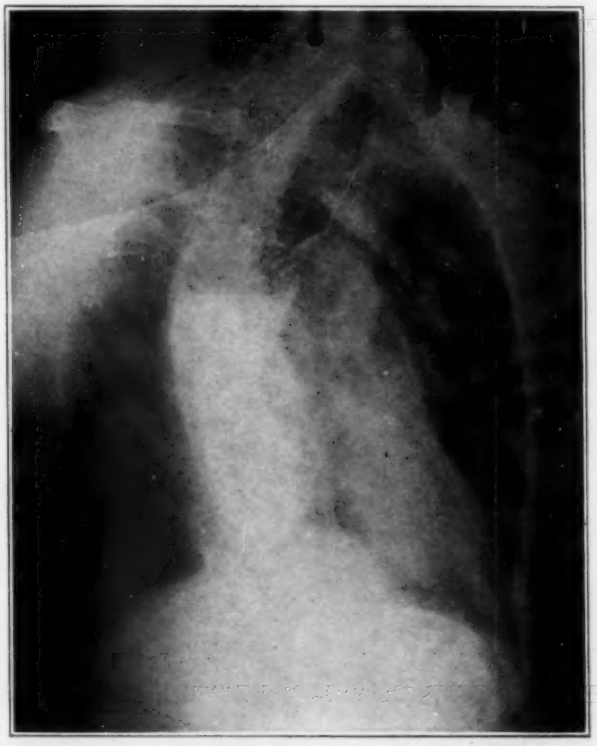

Fig. 4.—Roentgenogram showing enormous esophageal dilatation resulting from cardiospasm.

She has, however, complained of gas and a feeling of fulness in the left upper portion of the abdomen.

ACHALASIA OF THE ESOPHAGUS

Case 6.—A white man aged 63 gave a history of having had spells of being unable to eat for forty years. These spells would last about three weeks. Eight years ago he had a severe attack. At that time he was treated with esophageal dilations. For the past eight years he had eaten only strained foods. Six weeks prior to entering the hospital he had an acute exacerbation of his trouble and for the past six weeks had been unable to take even strained foods. If he took food,

he would have a feeling of fulness in the chest and pain in the epigastrium. He would get some relief from induced vomiting. Esophagoscopic examination was attempted, but it was impossible to pass a tube or any dilating instrument. At operation a thoracicoabdominal incision was made. The pleura was free. The pulmonary ligament was divided and the diaphragm split. As the incision in the diaphragm approached the esophageal hiatus, the muscles of the crura of the diaphragm were observed to be hypertrophied to at least twice the normal size. The esophagus was tightly surrounded by the crura, so that not even the tip of a finger could be inserted through the esophageal hiatus. However, when the crura were dissected away from the eosphagus, there was no evidence of inflam-

Fig. 5.—Roentgenogram of the kidney after injection of air to show tumor of the adrenal gland.

mation or scarring. The narrowed part of the esophagus extended for about 4 inches (10 cm.) above the diaphragm. At this point I opened the stomach and inserted my finger into the esophagus. I was surprised to find that the esophagus was thin walled and that, even though the history was of forty years' duration and there had been repeated instrumentation, there was no evidence of scarring or thickening of the esophageal wall. Another interesting finding was that the esophagus was narrowed so that it admitted my finger with difficulty and that as the finger was introduced it was gripped by the esophagus. The feeling as my finger was pulled back and forth in the esophageal narrowing was exactly the

feeling one gets in making a rectal examination. With my finger still in place, I dissected down to the longitudinal muscles of the esophagus, but this did not relieve the sphincter-like action. I then made an esophagogastric anastomosis and a jejunostomy and closed the diaphragm around the stomach near the anastomosis. After putting in an underwater drain, the chest was closed. The patient is now able to eat without difficulty.

COMMENT ON BENIGN LESIONS OF THE ESOPHAGUS

I have described cases of two types of nonmalignant lesions of the esophagus resulting in narrowing of the lower end of the esophagus with dilatation above. In the one type there is widening of the esophageal hiatus in the diaphragm with relaxation of the crura, so that the stomach is herniated into the chest. The esophagus is short, and the constriction is due to inflammation and ulceration. In cases of this type regurgitation of stomach contents, especially with the patient in the recumbent position, is a prominent feature. Allison [5] stated that ulceration results from the lower end of the esophagus being constantly bathed by acid from the stomach. Knight [6] observed that after bilateral excision of the thoracic portion of the sympathetic chain there was diminished tone of the sphincters so that digital pressure on the abdomen readily returned the meal from the stomach to the esophagus. In these cases sympathetic control may be lacking.

In the other type, or achalasia, there is narrowing of the esophageal hiatus with hypertrophy of the crura of the diaphragm and increased tone of the esophageal sphincter. The esophagus is longer, but there is no inflammatory reaction either in the wall of the esophagus or around the esophagus. Knight [6] stated the belief that there is a sphincter of the esophagus but that the presence of an anatomic sphincter is extremely difficult to demonstrate and has frequently been denied. I felt that in the case I have described I could definitely say that there was a sphincter.

Jackson [7] described a diaphragmatic pinchcock action in cardiospasm. This I also feel was demonstrated in my case. Both Knight [8] and Ferguson [9] found that bilateral vagotomy reproduced the clinical and roentgenologic pictures of achalasia. Knight [8] relieved the obstruction produced by vagotomy by sectioning the sympathetic supply to the esopha-

5. Allison, P. R.; Johnstone, A. S., and Royee, G. B.: Short Esophagus with Simple Peptic Ulceration, J. Thoracic Surg. **12**:432, 1943.

6. Knight, G. C.: The Relation of the Extrinsic Nerves to the Functional Activity of the Esophagus, Brit. J. Surg. **22**:155, 1934.

7. Jackson, C.: The Diaphragmatic Pinchcock in So-Called Cardiospasm, Laryngoscope **32**:139, 1922.

8. Knight, G. C.: Sympathectomy in the Treatment of Achalasia of the Cardia, Brit. J. Surg. **22**:864, 1935.

9. Ferguson, J. H.: Effects of Vagotomy on the Gastric Function of Monkeys, Surg., Gynec. & Obst. **62**:689, 1936.

geal sphincter. It would seem, therefore, that achalasia of the esophagus results from loss of vagus control. The question arises in my mind as to whether the innervation of the crura and the control of the esophageal hiatus are entirely through the phrenic nerve.

APPROACH TO THE ADRENAL GLAND AND THE UPPER POLE OF THE KIDNEY

The last case, that of a 12 year old girl with an adrenal tumor, illustrates the possibilities of transdiaphragmatic approach to organs lying

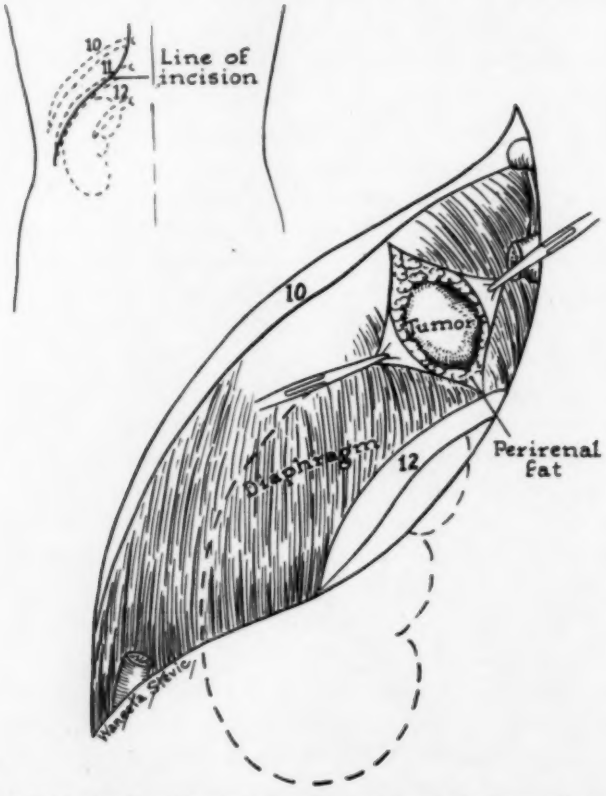

Fig. 6.—Artist's drawing illustrating transdiaphragmatic retroperitoneal approach to the adrenal gland and the upper pole of the kidney.

below the diaphragm. The patient had the characteristic picture of Cushing's syndrome. Roentgenograms of the kidney after injection of air demonstrated a tumor of the adrenal gland about 2 inches (5 cm.) in diameter. The child weighed nearly 200 pounds (90.7 Kg.), making the abdominal approach seem difficult. The usual approach to the kidney would have necessitated considerable manipulation before the tumor could have been delivered. In manipulating such a tumor, there is

danger of rapid rise in blood pressure. For these reasons, the tumor was approached from above. The eleventh rib was removed, the pleura opened and a 3 inch (7.5 cm.) incision made in the diaphragm retroperitoneally over the upper pole of the kidney. As soon as the diaphragm was opened, the perirenal fat was encountered. When the fat was separated, the tumor presented at once. A ligature was placed around the pedicle of the tumor, shutting off its blood supply, and the tumor was removed with no appreciable alteration in blood pressure. The approach to the adrenal gland and the upper pole of the kidney with a transdiaphragmatic, retroperitoneal approach is simple and practical.

ADVANTAGES AND DISADVANTAGES OF THE THORACICO-ABDOMINAL INCISION

The main advantage of the operation is that the exposure is much better than either the thoracic or the abdominal approach and it allows the surgeon to operate in both cavities at once. Being primarily a thoracotomy, it has the advantages of a thoracotomy over a laparotomy in that the patient can be carried in a lighter plane of anesthesia, with less danger from infection of the respiratory tract or from embolism. The wounds generally heal more rapidly and are less likely to break down. On the other hand, a thoracic wound is more likely to be painful than an abdominal wound, and 2 of my patients complained of a feeling of fulness in the left upper quadrant of the abdomen. This was probably due to interruption of the phrenic nerve.

CONCLUSION

Structures in the upper portion of the abdomen can be approached easily and adequately through a thoracic incision if the diaphragm and costal arch are divided. The technical procedure is not difficult, and the postoperative course is not complicated by the diaphragmatic incision. Cases of carcinoma of the cardia and esophagus, diaphragmatic hernia, peptic ulcer of the esophagus and achalasia of the esophagus have been presented to illustrate the usefulness of the approach. Unusual pathologic conditions around the esophageal hiatus have been encountered by dividing the diaphragm. It is felt that as more operations of this type are performed the pathologic and physiologic processes in the region of the esophageal hiatus will be better understood. A transdiaphragmatic retroperitoneal approach to the adrenal gland and the upper pole of the kidney has been used and found to be simple and practical.

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DISCUSSION

DR. JOSEPH W. GALE, Madison, Wis.: Dr. Harper has discussed the advantages and disadvantages of the thoracicoabdominal approach to the upper part of the

abdomen and has cited 6 interesting cases in which he employed this incision. He has spoken, correctly I feel, of the region of the lower part of the esophagus and the cardiac end of the stomach as the "no man's land in surgery." I shall not discuss the conditions for which this incision has been used but shall confine my comments to the approach. Several months ago, while discussing this problem with Dr. Harper, I stated that my colleagues and I had not used this approach, but that, if the occasion arose, we should certainly try it. Since then we have had several cases of diaphragmatic hernia and carcinoma of the lower end of the esophagus. In each instance only the thoracic approach was necessary. The only case in which the thoracicoabdominal incision was employed was for the removal of a large adherent spleen. The technic in this case consisted of an incision in the eighth intercostal space, extending from the angle of the ribs forward and downward through the costal margin. The exposure which was obtained was perfect, the operation greatly simplified and the patient's postoperative course uneventful. All realize that conclusions drawn from 1 case are based on too meager an experience to be of much value. In the past, we have had a group of thoracicoabdominal cases in which the application of this approach would have simplified the surgery. Ordinarily, for thoracic operations we sacrifice a rib, but in cases in which the incision also opens the peritoneal cavity we believe that an intercostal incision is preferable. The approximation of the thoracic wall is simple after the costal margin is sutured. The postoperative pain can be greatly reduced by crushing the neighboring intercostal nerves just anterior to the angle of the rib above and below the incision.

One must not overlook the added difficulties and possibilities of complications in this combined operation. If the thoracic cage is opened, respiration must be kept under control in order to have a clear view of the operative field. This demands an anesthetist who is well trained. Again, there is the problem of reexpanding the lung and obliterating the dead space as rapidly as possible to forestall infection, atelectasis and pleural effusion. I believe that with the proper personnel this approach has advantages far greater than the abdominal approach. The casual operator, who does not see many cases with lesions in this region, finds it extremely difficult to expose this area. Through the use of the approach which Dr. Harper has described, exposure is much more satisfactory, and the operator does not have to waste time and traumatize tissues, which is frequently the circumstance when the operation is attempted from below. Dr. Harper did not mention it, but I believe he will find that the site of the incision will vary, depending on the habitus of the patient. In the pyknic patient it will probably have to be placed higher, whereas in the asthenic type it may be one or two ribs lower.

FUNCTIONAL SURVIVAL OF AUTOGENOUS AND HOMOGENOUS TRANSPLANTS OF BLOOD VESSELS

An Experimental Study

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AND
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ROCHESTER, MINN.

THE FREQUENCY with which vascular injuries resulting from the war and from highway and industrial accidents are being encountered in everyday surgical practice indicates that all available knowledge of the poorly understood specialty of vascular surgery should be more widespread. It is this thought which leads us to believe that the experimental findings, about to be reported, are timely.

In this study we propose to invite attention again to some of the experimental observations that we have reported over a period of years, as well as to new data on the subject of transplantation of blood vessels. A part of the data to be presented at this time has been published previously in connection with studies made in this laboratory on the autogenous and homogenous transplantation of the kidneys. The transplants of blood vessels necessary to accomplish the renal transplants were mentioned only casually as they applied to the other studies. Therefore at this time these studies will be reviewed again briefly, and the newer studies which have been made on vascular transplants per se will be presented in detail.

Over the past two decades the surgical prerequisites for successful vascular suturing have become so well standardized and known to surgeons who are interested in this procedure that they will not be described at this time. It will suffice to say that all operations in the experiments about to be reported, in which success depended to a great extent on vascular suture, were based on the original vascular suturing technic of Carrel [1] and of Guthrie,[2] with the addition of some modifications

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1. Carrel, A.: The Surgery of Blood Vessels, etc., Bull. Johns Hopkins Hosp. **18**:18-28 (Jan.) 1907.

2. Guthrie, C. C.: Blood-Vessel Surgery and Its Applications, New York, Longmans, Green & Company, 1912, p. 120.

which have been developed in this laboratory over a period of years. The literature on the technic of vascular surgery contains so many reports of successful vascular suture by surgeons from all parts of this and other countries that we seem justified in concluding that the general principles of this type of surgery are tested by time. A good functional result can be expected from vascular suture if the principles of the technic are followed carefully.

The vascular surgeon is confronted frequently with cases in which there is need of vascular repair as a result either of a major loss of critical vascular substance or of such severe damage to the vessels in the part as to render their use undesirable or impossible. In such cases the desirability of replacing the injured segment of vessel with normal structures from either the patient or a donor is great. Information on either type of these transplants is meager and inconclusive. The result is that, more often than not, the surgeon confronted with such a situation sacrifices the part by amputation, rather than take a chance on saving it by attempting a vascular transplant.

It is well established that tissues from one part of the body can be moved to another site and survive provided an adequate blood supply is available in the new location. When body tissues have been removed from one location in the body to another, as occurs in skin grafting for instance, the blood supply for the graft in the new location is dependent for survival on the infiltration of newly developed blood vessels. The term "transplantation," when used in contradistinction to "graft," means the movement of a body structure from one location to another in the same or another subject, with the reestablished blood supply in the new location. The blood supply in the new location is established in the cases of transplantation by uniting the major artery and vein of the transplant to suitable vessels at the host site. The term "homogenous transplant" indicates that the transplanted tissue or structure was taken from a donor and placed in another subject of the same species.

It is readily seen from this definition of a transplant that, in the light of present knowledge, not many body structures are available for transplantation. An organ such as the kidney is readily adaptable to such an operation, and so are sections of both arteries and veins. Vascular transplantation would be especially valuable if sections of normal vessels could be used to replace vessels which have been damaged as a result of trauma or disease. Thus many amputations might be avoided if the removal of a segment of a blood vessel from a highly vascular region to a region not so well supplied, because of damage to the normal vessels, could be relied on to meet the vascular needs of the injured part.

In earlier communications, one of us (C. S. W.)[3] reported that after autogenous renal transplantation the kidney that had been removed

3. Williamson, C. S.: Some Observations on the Length of Survival and Function of Homogenous Kidney Transplants: Preliminary Report, J. Urol. **10:**

from its normal abdominal location to a new location in the neck of the experimental animal would sustain the renal health of the animal normally. In these experiments the renal artery and the renal vein were joined to the carotid artery and the jugular vein, respectively, by means of an end to end anastomosis. The ureter was disposed of by bringing it to the surface of the neck through a stab wound. The other kidney was removed, either at the time of the transplantation or within a short time after it had been done. In previous investigations Dederer [4] had shown that an autogenous renal transplant would function satisfactorily. These results were confirmed and expanded by other investigators.[5]

Homogenous renal transplants, made in exactly the same manner as the autogenous ones, survived only a short time. However, immediately after transplantation and for a period of one to usually not more than seven days after operation, the two types of transplants responded to the same tests in essentially the same manner. But after a period of only a few days all the homogenous transplants ceased to function. During the functional life of the transplants the chemical composition of the blood of the animal was within normal limits, even though the normal kidneys had been removed. Histologic studies of the transplanted kidneys, after they had ceased to function, indicated that the failure came as a result of highly destructive nephritis. The destructive process involved both the glomeruli and the tubules of the kidney. Formation of a thrombus at the site of the vascular anastomosis was an infrequent cause of failure. In some instances the thrombus that was formed was associated with technical errors committed at the time of operation. Kinking and torsion of the vessels as a result of poor placement of the kidney in the neck at the time of operation were also an occasional cause of failure. Carrel and Guthrie [7] reported the

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275-287 (Oct.) 1923; Further Studies on the Transplantation of the Kidney, ibid. **16**:231-253 (Oct.) 1926.

4. Dederer, C.: (*a*) Studies in the Transplantation of Whole Organs: I. Autotransplant of the Left Kidney to the Neck with Right Nephrectomy in the Dog, J. A. M. A. **70**:6-9 (Jan. 5) 1918; (*b*) Autotransplantation of the Kidney, ibid. **73**:1836-1838 (Dec. 13) 1919.

5. Holloway, J. K.: The Effect of Diuretics on Transplanted Kidneys, J. Urol. **15**:111-131 (Feb.) 1926. Ibuka, K.: Function of the Autogenous Kidney Transplant, Am. J. M. Sc. **171**:407-420 (March) 1926; Function of the Homogenous Kidney Transplant, ibid. **171**:420-433 (March) 1926. Wu, P. P. T., and Mann, F. C.: Histologic Studies of Autogenous and Homogenous Transplants of Kidney, Arch. Surg. **28**:889-908 (May) 1934.

6. Footnote deleted by authors.

7. Carrel, A., and Guthrie, C. C.: Successful Transplantation of Both Kidneys from a Dog into a Bitch with Removal of Both Normal Kidneys from the Latter, Science **23**:394-395 (March 9) 1906.

successful transplantation of kidneys from one animal to another. One of Dederer's [8] homogenous renal transplants functioned for eighteen days. The earlier observers expressed the belief that failure in the transplantation of homogenous organs was due to technical difficulties, such as infection, formation of a thrombus or poor placement of the transplant. In the light of our own experiments which have been reported, and those about to be reported, we may conclude that failure of the transplanted blood vessels per se was not often a decisive factor in the failure of the renal transplant to survive in the homogenous group.

The data to be reported at this time were obtained from (1) experiments on transplants of whole organs in regard to the function, or lack of function, of the transplanted vessels and (2) experiments with the homogenous transplantation of blood vessels per se. Since the data on the first experiments have been reported in detail previously as they apply to the survival and function of both types of renal transplants, this discussion will be limited to the observations that were made on the transplanted blood vessels. The data on the latter were mentioned, but not emphasized, in the earlier publications.

After the surgical technic had been established for the autogenous renal transplantation it was unusual for one of these experiments to fail. It was still more unusual to have one fail because of vascular defects which were secondary to the suture technic employed in establishing the vascular anastomosis. The most common cause of failure in experiments of this type came as a result of stenosis of the ureteral opening at the point of emergence from the stab wound in the skin. When the ureteral opening became stenosed, hydronephrosis, infection and pyonephrosis were sure to conclude the experiment within a relatively short time. The fact that the transplant was dependent for survival on a free and adequate blood supply and that this type of transplant did survive for an indefinite time seems ample justification for the conclusion that such a blood supply was present. Grossly, when the kidney was removed for histologic study, it was frequently almost impossible to determine the site of the previous end to end anastomosis between the vessels. Careful dissection of the vessels at the site of union revealed a minimal amount of deformity and scarring in both the artery and the vein. From these observations we felt justified in concluding that the autogenous transplantation of blood vessels, both artery and vein, could be undertaken with a reasonable expectation of a successful result. In order to obtain this result, however, great attention must be given to the details of the suturing technic as well as to the care afforded the vessels while the operation is in progress. Blood vessels about to be sutured cannot be allowed to become dry or be handled roughly if the repair is to be effective.

8. Dederer, C.: Successful Experimental Homotransplantation of the Kidney and the Ovary, Surg., Gynec. & Obst. **31**:45-50 (July) 1920.

Homogenous renal transplants all failed to survive for any great length of time. After an operation of this type, which differed from the autogenous experiments only in that the kidney which was transplanted was taken from a donor animal and planted in the neck of the recipient, there was in the beginning little difference in the functional behavior in the two types of experiments. This similarity was of short duration. It lasted only for a few hours to a few days. During the time in which the transplant was functioning it would sustain the animal in a normal state of renal health if its own kidneys had been removed. But when the transplants ceased to function—and they all did after varying lengths

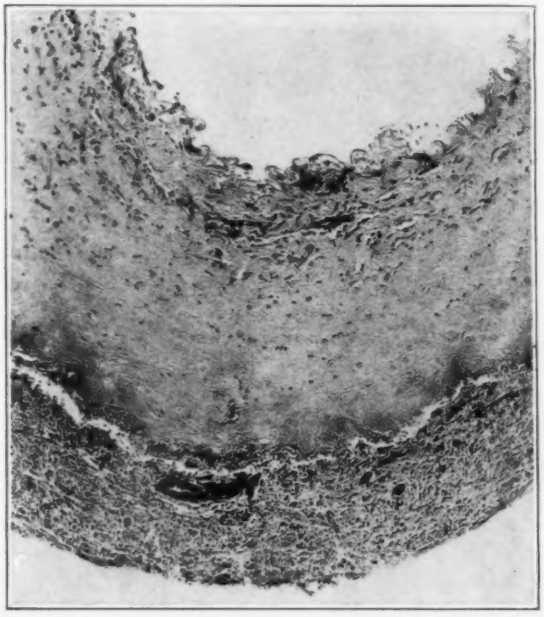

Fig. 1.—Wall of homogenous arterial transplant of fifty-six days' duration. Section was taken from region adjacent to the thrombus; × 75. Compare with figure 4.

of time—symptoms of renal insufficiency developed and the animals died. The cessation of function in this type of transplant was so rapid that at first we believed it to be due to an accident, such as a thrombus, or possibly kinking, of the renal vessels. Further observations convinced us that the failure in most instances was biologic rather than mechanical in nature. It was only occasionally that the blood vessels were incriminated in the failure directly. The facts that after the kidney had ceased to function and had been removed for histologic study the blood vessels were more often than not in a good functional condition and, further, that no other mechanical defects which might explain the failure could

be located lead us to believe that the agent in these failures was probably related to tissue specificity. This would explain why autogenous transplants would survive indefinitely whereas homogenous ones would survive for, at most, only a few days.

In view of these observations, it seemed to us that, since the kidney is a highly specialized structure and usually ceased to function while the blood vessels that supplied it were in a functional state, blood vessels, which are relatively simple structures, might survive for longer periods under similar conditions of transplantation. In order to determine this

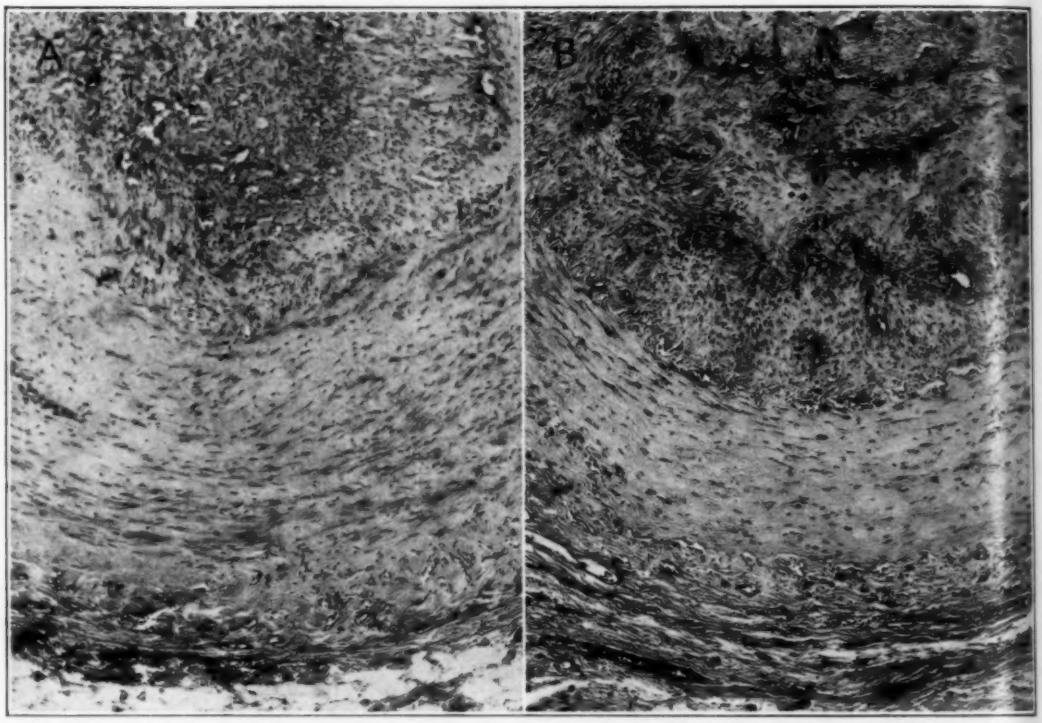

Fig. 2.—*A*, wall of artery and, *B*, wall of vein. In each case, the vessel was a homogenous transplant of fifty-six days' duration. Section was from region of the thrombus; × 70.

point, a series of 6 medium-sized dogs were selected at random for the studies. This group of animals was divided into three pairs so that both animals in each pair would act both as a donor and as a recipient. With the animals under ether anesthesia and with the use of aseptic technic, sections from the carotid artery and the jugular vein of each animal were removed and exchanged for similar sections removed from the same vessels of the other member of the pair. The sections which were removed were about 6 cm. in length. Thus, at the conclusion

of the operation animal 1 had transplanted segments of the carotid artery and the jugular vein of animal 2, while animal 2 had similar segments of the corresponding vessels from animal 1. The transplanted segments of the artery and vein were allowed to remain in place for an elapsed time of fifty-six to sixty-two days and then were removed for histologic study.

OBSERVATIONS

On Dec. 11, 1945 segments of artery and vein were transplanted from animal 1 to animal 2 and from animal 2 to animal 1. On Feb. 5, 1946 the transplanted vessels were removed for histologic study. Grossly, there was no function in either the

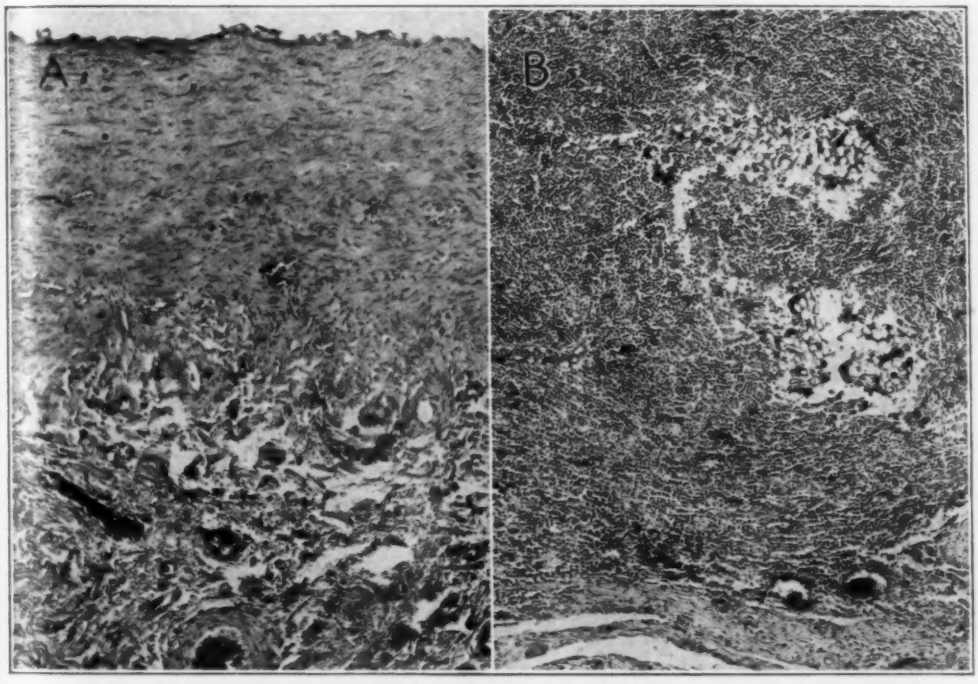

Fig. 3.—*A*, wall of artery, and, *B*, wall of vein. In each case the vessel was a homogenous transplant of sixty-one days' duration. Note vascularity in *A*. Sections from region adjacent to the thrombus; × 70.

artery or the vein from animal 1. There was moderate inflammation around the operative site. Microscopically, the muscle fibers of the media of the artery were well defined. There was well defined development of capillaries between the intima and the media, with some of the capillaries extending between the muscle strands of the media. The cellular boundary between the intima and the lumen was poorly defined. The thrombus in the lumen was spongy and contained many sinuses filled with normal-appearing blood cells (fig. 1).

Grossly, there was no evidence of function in the transplanted artery and vein from animal 2. Microscopically, in the artery there were a few small capillaries between the muscle fibers of the media. Some capillaries extended through nearly the entire thickness of the wall. The intima was thickened and in some regions

had been replaced by fibrous tissue. The thrombus was spongy and contained many large sinuses (fig. 2 *A*). The vein showed simple thrombosis (fig. 2 *B*).

On Dec. 5, 1945 segments of artery and vein were transplanted from animal 3 to animal 4 and from animal 4 to animal 3. On Feb. 5, 1946 the transplanted vessels were removed. Grossly, there was considerable reaction about the operative site in animal 3. There was no evidence of function at this time. Microscopically, there was intense inflammation around the artery. The muscle fibers were fairly well preserved. The intimal lining of the artery was largely destroyed and replaced by fibrous tissue. The margin between the thrombus and the intima was poorly defined. The thrombus contained many capillaries (fig. 3 *A*). Few

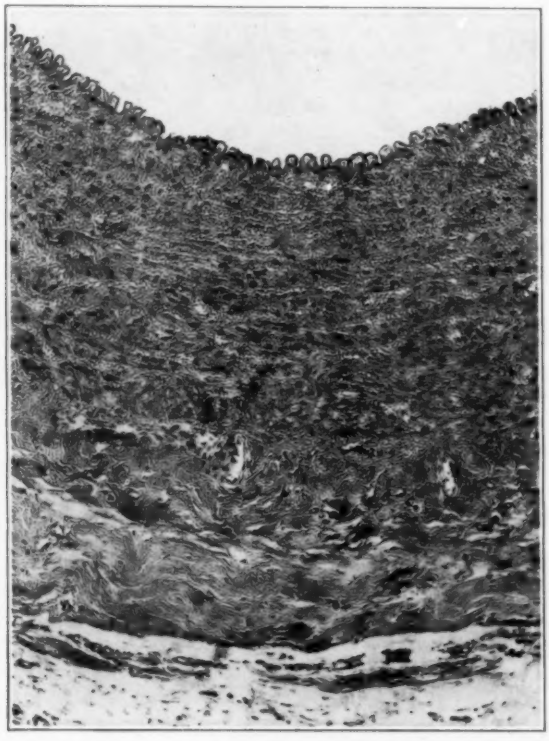

Fig. 4.—Wall of the carotid artery, which had been sutured and anastomosed in situ sixty-five days previous to removal. Section was taken from region adjacent to the anastomosis; × 75.

structures in the vein had survived. Intense inflammation was present. There was well developed sinus formation in the thrombus. The destructive process was much greater in the vein than in the artery (fig. 3 *B*).

Grossly, there was minimal reaction of the tissues at the operative site in animal 4. The artery was functioning, but the vein was thrombosed. Microscopically, there was intense reaction of the tissues with severe destruction of venous structures and replacement by fibrous tissue. The vascular walls had been invaded by extension of fibrous tissue from the thrombus. The thrombus was well organized and contained septums. There were many large capillaries in the wall of the artery. The intima was normal except in one region, where there was a break of continuity, with the margins well defined. Around part of the circum-

ference of the lumen there was a densely adherent thrombus, but this did not seem to have impeded circulation materially.

On Dec. 5, 1945 sections of artery and vein were transplanted from animal 5 to animal 6 and from animal 6 to animal 5. On Feb. 6, 1946 the transplanted vessels were removed. Grossly in animal 5 there were mild reaction in the tissues about the artery and more severe reaction about the vein. Neither vessel was functioning. Microscopically, the wall of the vein was much degenerated, with replacement of normal venous structures by fibrous tissue. Some of the fibrous tissue extended into the thrombus, which filled the lumen. The thrombus was divided by septums, in each of which were capillaries. In the artery there was very moderate replacement of normal vascular structures by fibrous tissue. The normal intimal outline had been obliterated. The lumen contained an extensive thrombus, which showed minimal formation of capillaries.

In animal 6 the gross tissue reaction around the transplanted vessels was moderate. Neither vessel was functioning so far as could be determined grossly. Microscopically, the arterial wall was well preserved, with minimal replacement by fibrous tissue. In the lumen of the artery there was a thrombus, which was well organized at the periphery but spongy in the central region. In this region there were many blood cells, suggesting that some function remained.

The carotid artery of animal 7 was sutured end to end. When the region of operation was examined grossly sixty-five days later, it was difficult to determine the site of suture, and the functional result was good. Microscopically, there was no fibrous infiltration of the vascular walls. The intima had the normal serrated outline, and there was no evidence of formation of a thrombus (fig. 4).

COMMENT

Thus it is seen in the foregoing protocols that of the 12 operations, 6 venous transplants and 6 arterial transplants, 10 had become nonfunctional after an elapsed time of fifty-six to sixty-two days. One arterial transplant was in a grossly functional state at the time of removal; and another, the functional state of which could not be determined grossly, was observed to be functioning to a limited extent when examined histologically. All the venous transplants had ceased to function at the time of removal, and the remaining arterial transplants had also ceased to function. The results in 1 of the animals was compromised by a severe postoperative infection. Grossly there was nothing to account for the failure of the vascular transplants to survive. The histologic picture in both the arteries and the veins varied widely but was consistent in some respects in all the experiments.

The most common histologic feature in all thrombi in both arteries and veins was the tendency to vascularization in the thrombi, which occluded the lumens of the vessels. This vascularization also included the walls of the vessels themselves. These new-formed blood vessels were in some instances fairly large and were evidently serving as conduits for a considerable amount of blood in both the arterial and the venous transplants. The thrombi which were present in the arterial transplants had in some instances a spongy appearance, but those in the veins were

more solidly organized and there was a decided tendency for the clot to be divided into segments by fibrous septums.

The destructive process in the arteries was less severe than in the veins, and there was also a greater tendency to canalization of the thrombi. In general the intima of the arteries was fairly well preserved, but in a few instances it had been largely destroyed and replaced by fibrous tissue. The muscle fibers of the media were also fairly normal in number and arrangement, but in some of the vessels in which the reaction had been severest many of the muscle fibers and much of the elastic tissue had been replaced by fibrous tissue. In summary, it can be said that the structure of the arterial walls of the transplanted segments of vessels had not been severely damaged except in a few instances.

Uniformly, the destructive process in the sections of the transplanted veins was complete. All the veins were thrombosed, and, while there was a tendency to vascularization of the thrombi, this process was not pronounced. The thrombi were more solidly organized and seemed to be more firmly attached to the walls of the veins than they were in the arterial transplants. The venous walls themselves were for the most part poorly preserved. There was extensive replacement of the normal mural structures with fibrous tissue, and in some regions this replacement was almost complete. An explanation of the severity of the reaction in the veins is not obvious. In all the transplants, both arterial and venous, there was a tendency to vascularization of the walls of the vessels, as well as of the thrombi which occluded the lumens. This characteristic was most pronounced in the arterial transplants. In some instances this development had progressed enough to be considered important as a channel for the arterial circulation. The status of these vessels in relation to the ultimate survival of the transplants remains a problem for future investigation.

SUMMARY

We wish to emphasize the following points:

1. The technic of vascular surgery is well established, and the surgeon who is willing to accept the requirements necessary for success in this work can expect satisfactory end results in the main.

2. The autogenous transplantation of both arteries and veins is a feasible surgical procedure in the light of present knowledge.

3. Homogenous transplantation of blood vessels, as well as other body structures, is not justified in the light of present knowledge.

4. There is a striking tendency for capillaries to develop in both the thrombus and the wall of the vessel in homogenous vascular transplants. This tendency is most conspicuous in the arterial transplants.

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DISCUSSION

DR. ERWIN R. SCHMIDT, Madison, Wis.: It is with a feeling of some temerity that I come here to discuss this excellent paper, but I cannot let the opportunity pass without making some comments.

First, this study probably represents the secret ambition of every clinician to do some basic scientific research. At a meeting not long ago, it was pointed out to the clinical men that most of the basic scientific research underlying progress in medicine has been done by the doctors of philosophy; I did not want to argue the point, but I know that a great deal of such basic research has been done by clinical men.

Second, it is the business of every clinical man to encourage and foster and to help people who are interested in this type of work. I do not decry the clinical papers, for they are important, but, in order for progress to be made, this basic scientific work must be done.

Third, the problem which the authors have presented has far reaching values in clinical medicine, applications which may not now be appreciated. It is related to the problems of hypoxia. Many years ago pathology was of the virchowian, gross type, and so gross that almost any one could make the diagnosis. The science has made great progress, and now one is concerned with minimal pathologic changes. In other words, the physician is making an earlier diagnosis, is being more careful and is giving the patient much better service.

I feel that the problem of the reaction of tissue to lack of oxygen has to some extent been overlooked by all members of the medical profession. Only in the last ten years has it come to their attention.

I told Dr. Williamson that I felt his problem in vascular transplantation was related not so much to the mechanics of the anastomosis, although this is important, as to the question of hypoxia and, more than that, probably of anoxia.

As to specificity of tissue response, it is known that the various tissues in the body may suffer in varying degrees from lack of oxygen; for instance, certain types of brain cells will be injured much more severely than others.

For example, in the kidney, there are differences in reaction in the glomerulus and the ascending and descending portions of the tubule. Therefore postmortem examination reveals many pathologic changes which can be interpreted as the effect of lack of oxygen on a particular tissue. Comparable changes can be seen in the liver as a result of want of oxygen. The liver has such tremendous reserve that the surgeon can go on with his procedures and have little idea of the functions of this organ or of what strain he can put on it. Thus, it is these minimal reactions which should be investigated, and I think this paper is an excellent attempt at such a study.

The question of the susceptibilities of the brain and kidney have been studied, and the observations incorporated into clinical experience. It has been only within the last few years, as a result of Brooks's work on gangrene, that the entire concept of the handling of inflammations has been changed. In cases of senile gangrene, instead of elevating the extremities, one now keeps them flat. It is known that by keeping the limb level the venous pressure is increased, and this raises the capillary pressure.

It is known, furthermore, that if the temperature is reduced locally there is more chance of that tissue surviving. The basal metabolic rate is depressed, and the oxygen brought there is sufficient to carry the tissue over the trying period. These are observations which have been adopted in clinical medicine.

There is a great demand for such investigations at the present time because of the recent large amount of trauma. Vascular surgery is important in cases of

trauma, and great advances have been made during the war. For instance, early surgical intervention in cases of arteriovenous aneurysm results in trouble, and so one waits until collateral circulation has developed. If operation is performed early, the blood supply is insufficient; there is a lack of oxygen, and gangrene intervenes. If one waits until collateral circulation has developed, one has sufficient blood supply and adequate oxygenation, and the limb will survive.

As a result of the work done in this country—and done by clinical men, among whom are Blalock, Blackmore and, recently, Potts, of Chicago—notable advances have been made in vascular surgery. After listening to this paper by Dr. Williamson and Dr. Mann, I feel that one may look for further advances in surgery of the circulatory system.

Dr. Carl S. Williamson, Albuquerque, N. M.: I want to thank Dr. Schmidt for his discussion of this paper. He has given me some ideas which I shall take home and try to follow through. I might say that no one was more surprised than we at what we found in these experiments.

Because of our previous experience with homogenous renal transplants, we felt that it was only a matter of form to make these experiments and confirm the assumption that all the transplants would cease to function within a very short time.

However, owing to the fact that of 12 transplants, 2 were functioning after a considerable period, we now wonder whether we took the transplants out too late or too early. In other words, we wonder what would have happened if we had left them in for a longer time and, also, what would have happened if we had taken them out earlier. We hope to find the answer to these questions in a future study.

BLOOD IODINE STUDIES

VIII. The Blood Iodine in Nonthyroid Disease

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AND
M. BEEN FERTMAN, M.D.
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THE LEVEL of the blood iodine has been widely recognized as a valuable diagnostic aid in differentiating thyroid from nonthyroid disease. Consequently it becomes of importance to determine whether or not blood iodine values ordinarily deviate from the normal in diseases other than of the thyroid gland. Moreover, it is necessary to learn the degree of deviation as well as the nature of the pathologic states in which such variations may occur. Too, any abnormality in the level of the blood iodine in nonthyroid disease might suggest that the thyroid gland was either primarily or secondarily involved.

In contrast to those involving the thyroid gland, nonthyroid diseases in general affect the basal metabolic rate less characteristically [1] and even more seldom cause an increase or decrease of the blood iodine. This was revealed by an investigation of representative patients with one hundred and fifteen different nonthyroid diseases (tables 1, 3 and 4). Moreover, deviations of average blood iodine values from normal were, with one exception, increases (table 1) and were not necessarily accompanied by any apparent increase or decrease of the basal metabolic rate.

HEPATIC AND BILIARY DISEASE

In 11 patients with chronic cholecystitis, accompanied in all but 2 by cholelithiasis, the average blood iodine was significantly elevated, even in the face of a normal average basal metabolic rate.[1b] Moreover, the elevation was commensurate with that found in patients with toxic goiter [2] (tables 1 and 2). The two lowest values for blood iodine in

From The Department of Research Surgery of The Ohio State University.

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1. Curtis, G. M., and Fertman, M. B.: (*a*) Blood Iodine Studies: VII. The Basal Metabolic Rate and Its Relation to the Blood Iodine in Thyroid Disease, Ann. Surg., **122**:963, 1945; (*b*) IX. The Basal Metabolic Rate and Its Relation to the Blood Iodine in Non-Thyroid Disease, to be published.

2. Curtis, G., and Fertman, M. B.: Blood Iodine Studies: VI. An Analysis of the Blood Iodine in Thyroid Disease, Arch. Surg. **50**:207 (April) 1945.

TABLE 1.—*The Average Blood Iodine in Nonthyroid Disease Plus or Minus the Standard Error Compared With That in Hyperthyroidism*

Clinical Diagnosis	Chromium Trioxide [12] Method		Dry Ash Method [11]	
	No.	Micrograms/ 100 Cc.	No.	Micrograms/ 100 Cc.
Normal persons	39	4.2 ± 0.2	16	11.9 ± 0.8
Diabetes mellitus	3	4.5 ± 0.7	3	7.6 ± 0.3*
"Endocrine imbalance"	3	3.7 ± 0.4	1	19.0
Pituitary dwarfism	..	.....	2	7.3 ± 0.8
Acromegaly	2	3.2 ± 0.1	..	.....
Hirsutism	5	3.8 ± 0.4	..	.....
Hypopituitarism	4	4.8 ± 0.6	2	10.5 ± 2.2
Froehlich's syndrome	2	6.2 ± 1.1*	..	.....
Addison's disease	2	5:0 ± 0.5	2	8.0 ± 2.6
Mongolism	..	.....	8	15.1 ± 1.6
Obesity	15	4.1 ± 0.3	4	8.3 ± 1.3
Menstrual disturbance	6	4.1 ± 0.5	1	17.2
Chronic cholecystitis	11	7.0 ± 1.0†	2	13.0 ± 1.3
Mixed group of hypertensive conditions	14	5.1 ± 0.7	14	17.0 ± 2.4*
Nonhypertensive cardiac disease	4	4.4 ± 0.4	3	13.5 ± 1.5
Aortic aneurysm	2	3.7 ± 1.2	..	.....
Chronic nephritis	2	4.1 ± 0.5	1	9.8
Secondary anemia	1	3.7	3	10.1 ± 1.5
Agranulocytosis	..	.....	2	12.6 ± 0.2
Myelogenous leukemia	3	4.4 ± 0.6	6	14.0 ± 2.5
Lymphatic leukemia				
Men	..	.....	2	19.2 ± 1.2†
Women	..	.....	3	8.6 ± 1.7
Hodgkin's disease	2	3.9 ± 0.5	..	.....
Splenomegaly of undetermined origin	2	4.1 ± 0.9	..	.....
Benign tumors	12	3.7 ± 0.4	1	8.7
Extrathyroid carcinoma	2	3.7 ±0.3	4	10.1 ± 0.9
Syphilis ‡	5	5.6 ± 1.1*	2	8.2 ± 1.7
Pulmonary tuberculosis	4	4.4 ± 0.3	7	10.4 ± 3.6
Tuberculosis of vertebra	..	.....	2	14.5 ± 7.3
Cervical lymphadenitis	2	4.3 ± 1.4	..	.....
Empyema thoracis	..	.....	2	16.1 ± 5.2
Bronchiectasis	..	.....	3	11.8 ± 4.6
Sinusitis	..	.....	3	10.7 ± 2.7
Mixed group of arthritic conditions				
Males	6	5.3 ± 0.5*	1	18.0
Females	9	4.1 ± 0.3	1	12.8
Pelvic inflammatory disease	3	3.2 ± 0.6	..	.....
Endocervicitis	..	.....	2	15:6 ± 7.7
Colitis	3	3.5 ± 0.2	..	.....
Migraine	9	4.0 ± 0.5	..	.....
Fatigue	..	.....	3	13.0 ± 4.7
"Functional disturbance"	26	4.0 ± 0.1	4	9.2 ± 1.2
Vagotonia	2	3.2 ± 0.5	1	9.3
Globus hystericus	3	5.5 ± 0.5	..	.....
Neurasthenia	8	4.0 ± 0.6	1	12.6
Psychoneurosis	17	4.0 ± 0.3	2	12.6 ± 2.5
Mental deficiency	2	4.2 ± 0.5	..	.....
Epilepsy	3	3.3 ± 0.2	..	.....
Allergy	4	5.3 ± 1.0	..	.....
Thyroglossal fistula	..	.....	2	8.8 ± 1.8
Hernia	8	3.9 ± 0.3	3	8.3 ± 1.5
Fractures	4	3.8 ± 0.2	..	.....
Toxic nodular goiter	29	7.9 ± 0.8†	28	15.8 ± 1.1*
Exophthalmic goiter	41	9.3 ± 0.6†	32	17.7 ± 1.1*

* Significantly different from normal (chances better than 20 to 1).

† Highly significantly different from normal (chances better than 100 to 1).

‡ In 2 of the 5 syphilitic patients in the chromium trioxide group arsenical hepatitis was also recognized.

this group, both low normal, occurred in the 2 patients without cholelithiasis. In the single patient with obstruction of the common duct the blood iodine was high but neither exceeded all other levels in this group nor was to any extent comparable with the tremendous values [3] found by De Courcy.[4]

Elevation of the blood iodine in disease of the liver or of the biliary tract is of especial interest because of the important role the liver presumably plays in iodine metabolism,[5] a role relegated by De Courcy specifically to the Kupffer cells.[6] It has been shown that the iodine content of the bile is consistently high,[7] so high, in fact, that this con-

TABLE 2.—*The Average Blood Iodine Values Which Differ Significantly from Normal Together with Their Corresponding Basal Metabolic Rates, Compared with Those in Hyperthyroidism*

	Average Blood Iodine, Chromium Trioxide Method [12]		Average Basal Metabolic Rate, Dry Ash Method [11]			
Clinical Diagnosis	No.	Micrograms /100 Cc.	No.	Micrograms /100 Cc.	No.	%
Normal persons	39	4.2	16	11.9	46	—5
Diabetes mellitus	3	4.5	3	7.6*	5	—1
Froehlich's syndrome	2	6.2*	..	....	2	—15
Chronic cholecystitis	11	7.0*	2	13.0	5	—2
Syphilis ‡	5	5.6*	2	8.2	4	—2
Hypertension						
All	14	5.1	14	17.0*		
Males	..	...	..	....	6	—2
Females	..	...	..	....	16	+12†
Arthritis						
All	..	...	..	....	11	—5
Males	6	5.3*	1	18.0		
Females	9	4.1	1	12.8		
Lymphatic leukemia						
Males	..	...	2	19.2†	2	+74†
Females	..	...	3	8.6	3	+19†
Toxic nodular goiter	29	7.9†	28	15.8*	54	+28†
Exophthalmic goiter	41	9.3†	32	17.7*	70	+40†

* Significantly different from normal.
† Highly significantly different from normal.
‡ Two of the 5 syphilitic patients in the chromium trioxide group also had arsenical hepatitis.
When there is a significant difference between males and females, the two values are listed separately.

3. Our own observations would lead us to think that these were due to recent administration of iodine, most likely the gallbladder dye with its high content of organically combined iodine.

4. De Courcy, J. L.: Iodine Metabolism, Normal and Abnormal: Its Relation to the Reticulo-Endothelial System, Tr. Am. A. Study Goiter, 1937, p. 133.

5. Elmer, A. W.: Iodine Metabolism and Thyroid Function, London, Oxford University Press, 1938, pp. 190 and 194.

6. De Courcy, J. L.: Further Study of Blood Iodine Changes in Affections of the Gallbladder, Surg., Gynec. & Obst. **65**:180, 1937.

7. (*a*) Libecap, I. L.: The Iodine Content of Normal Human Tissues, Thesis, Ohio State University, 1942. (*b*) King, J. D.: The Iodine Content of the Normal Thyroid Gland Correlated with Its Histology and the Iodine Content of Other Normal Body Tissues, Thesis, ibid., 1940.

centration is second in the human body only to that in the thyroid gland and in the hair.[7a] When the liver has been damaged, as in the hepatitis accompanying chronic cholecystitis or in certain other diseases the blood iodine has been noted to increase, often attaining levels even higher than those found in patients with hyperthyroidism.[8] De Courcy observed average concentrations of iodine in the blood ranging to one hundred times the normal level in patients with cholecystitis and cholelithiasis, [4] also occasionally in patients with carcinoma of the liver.[8b] He found levels up to one thousand times normal [8] in patients with obstruction of the common duct.[4] Lesser elevations were noted in acute cholangitis,[4] in hydrops of the gallbladder [8b] and in carcinoma of the gallbladder.[4] De Courcy was unable to explain why the iodine content of the blood in patients with portal cirrhosis was found normal.[9]

Different results were obtained by Cohn and Feldman, who could find no elevation of the blood iodine level in 4 patients with various diseases of the gallbladder and the liver. From this and from the observation that carbon tetrachloride, a substance producing degeneraton of hepatic cells, produces no significant change in the blood iodine of rabbits, they concluded that the functional relationship between the thyroid and the liver is not expressed by the blood iodine level.[10]

CARDIOVASCULAR AND RENAL DISEASE

Investigation of the blood iodine in patients with hypertension, together with the basal metabolic rate, is likewise of especial importance because of the occasional need to differentiate this disease from hyperthyroidism. Unfortunately, in this study as well as in others reported in the literature, it must be assumed that the clinical diagnosis of hypertension without hyperthryoidism was in all instances correct.

The average iodine level for whole blood, as well as the basal metabolic rate, was significantly elevated in one group of 14 patients with hypertension and hypertensive heart disease. These levels were determined by the dry ash method [11] (tables 1 and 2). In a subsequent group of 14 hypertensive patients, whose blood iodine was determined

8. (*a*) Footnote 4; (*b*) Iodine Content of Blood in Cholecystic Disease, Arch. Surg. **35**:140 (July) 1937.

9. De Courcy (footnotes 4 and 6).

10. Cohn, A., and Feldman, S. E.: The Relation Between the Liver and the Thyroid Gland: I. Blood Iodine as an Indicator of Liver Function, Am. J. Clin. Path. **12**:27, 1942.

11. Davis, C. B., and Curtis, G. M.: Blood Iodine Studies: I. The Quantitative Determination of the Iodine Content of Blood, J. Lab. & Clin. Med. **18**:24, 1932. Phillips, F. J., and Curtis, G. M.: Blood Iodine Studies: IV. The Clinical Determination of Iodine in Blood, Urine and Feces, Am. J. Clin. Path. **4**:346, 1934.

by the more recent chromium trioxide oxidation method,[12] the average blood iodine did not quite reach the 5 per cent level of significance.

From the total group of 28 patients with hypertension, there were in all 16 given a diagnosis of essential hypertension without cardiac disease. Of the 16, only 5 had elevated blood iodine values, and these were accompanied by basal metabolic rates ranging from plus 5 to plus 19. The blood iodine was normal in the only 2 patients with malignant hypertension, despite accompanying basal metabolic rates as high as plus 24 to plus 32.

Of the 7 patients with hypertensive heart disease without decompensation, only 1 had an elevated blood iodine level, while 2 of 3 with hypertension and congestive failure had increased blood iodine values. On the other hand, in 7 patients with nonhypertensive heart disease, 5 of whom were rheumatic, there was no elevation of the blood iodine, not even in the 2 patients with congestive failure.

Hyperiodemia has been noted in essential hypertension by several investigators.[13] Occasionally, blood iodine values as high as 100 micrograms per hundred cubic centimeters have been reported.[13b] Such a notable increase is primarily suggestive of iodine medication [14] rather than the presence of so severe a form of hyperthyroidism. Even proponents of the existence of hyperiodemia in hypertension expressed the belief [13c] that this increased blood iodine, which accompanies but does not parallel [13d] the elevated basal metabolic rate, indicates increased thyroid activity. Others reported normal [15] and also low normal levels of iodine in the blood,[15b] even in the face of basal metabolic rates as distinctly elevated as those in hyperthyroidism.[15b] The fraction of the

12. Matthews, N. L.; Curtis, G. M., and Brode, W. R.: Determination of Iodine in Biological Materials: Refinements of the Chromium Trioxide Oxidation Method, Indust. & Engin. Chem. **10**:612, 1938.

13. (*a*) Veil, W. H., and Sturm, A.: Beiträge zur Kenntnis des Jodstoffwechsels, Deutsches Arch. f. klin. Med. **147**:166, 1925. (*b*) Paal, H.: Elecktrochemische Blutjodbestimmung, Klin. Wchnschr. **14**:1394, 1935. (*c*) Burger, M., and Möbius, W.: Der Jod und Cholesteringehalt des Blutes in seinen Beziehungen zur essentiellen Hypertonie, ibid. **13**:1349, 1934. (*d*) Möbius, W., and Nolte, F. A.: Verhalten von Grundumsatz und Blutjod bei Thyreotoxikosen, Ztschr. f. klin. Med. **128**:174 1935; (*e*) Vergleichende Blutjoduntersuchungen bei trockener und feuchter Veraschung, Biochem. Ztschr. **253**:275, 1932. (*f*) Curtis, G. M.; Cole, V. V., and Phillips, F. J.: The Blood Iodine in Thyroid Disease, Tr. Am. A. Study Goiter, 1934, p. 142; West. J. Surg. **42**:435, 1934. (*g*) Curtis, G. M.: The Iodine Relationships of Thyroid Disease, Surg., Gynec. & Obst. **62**:365, 1936.

14. Lohr, H.: Beiträge zur Kenntnis des Jodstoffwechsels: I. Blutjodstudien unter physiologischen Verhältnissen, Arch. f. exper. Path. u. Pharmakol. **180**: 332, 1936.

15. (*a*) Lohr.[14] (*b*) Turner, K. B.; De Lamater, A., and Providence, W. D.: Observations on the Blood Iodine: I. The Blood Iodine in Health, in Thyroid and Cardiorenal Disease, and in Leukemia, J. Clin. Investigation **19**: 515, 1940.

blood iodine insoluble in acetone or water appears to be a more reliable criterion than the whole blood iodine in the differentiation of hyperthyroidism from hypertension, since in clinically euthyroid hypertensive persons it is low normal to even subnormal.[16]

Some have found the blood iodine increased in congestive heart failure,[15ag] while others reported normal values in this disease.[17] Kisch found the range of blood iodine values in nonhypertensive heart disease of various sorts to be normal in patients with elevated as well as in patients with normal metabolism.[17] Low blood iodine values, accompanying normal metabolism and serum cholesterol levels, have also been encountered in nonhypertensive heart disease, even when attended by congestive failure.[15b] Perhaps the occurrence of normal and low blood iodine in some patients with congestive failure may be explained in part by the therapeutic management of these conditions with digitalis, for on digitalization in the presence or absence of cardiac disease, hypertension or hyperthyroidism, a sharp drop in the blood iodine may ensue.[13a]

If renal function is sufficiently disturbed, a decreased urinary elimination of iodine with increased retention of iodine in the blood might be expected. An elevated blood iodine has been reported in renal failure.[18] We have found the blood iodine increased in 1 patient with anuria, who, however, also had hypertension and arteriosclerosis. On the other hand, the blood iodine as well as the basal metabolic rate may be low in renal disease without renal failure, as reported in 3 patients with glomerular nephritis,[15b] or normal, as observed in 3 patients in our series (table 1), 2 with chronic glomerular nephritis and 1 with chronic pyelonephritis.

BLOOD DYSCRASIAS AND DEGENERATIVE DISEASE

We could find no significant increase in the average blood iodine in 9 patients with myelogenous leukemia, despite a greatly elevated basal metabolic rate[1b] (table 1). Nevertheless, variation in the individual blood iodine values exceeded normal. A considerable elevation of the blood iodine accompanying an increased basal metabolic rate was encountered in 2 males with lymphatic leukemia (table 2). In one of these patients both the blood iodine and the basal metabolic rate declined to within normal limits two and one-half years following

16. Davison, R. A.; Zollinger, R. W., and Curtis, G. M.: The Fractionation of the Blood Iodine: I. Findings in Patients with Normal Thyroid Function and with Hypothyroidism, J. Lab. & Clin. Med. **27**:643, 1942.

17. Kisch, F.: Ueber des Verhalten des Blutjodspiegels Kreislaufkranker, Wien. klin. Wchnschr. **47**:1317, 1934.

18. Baldau, L. K., and Pincussen, L.: Untersuchungen über den Jod und Bromgehalt des Blutes, Klin. Wchnschr. **9**:1505, 1930.

splenectomy. Increase in the average basal metabolic rate of 3 females with lymphatic leukemia was moderate and was not accompanied by any elevation of the blood iodine. The significant difference in the average blood iodine values of the males and females with lymphatic leukemia (table 2) may have been due to various factors, such as the therapeutic management of the disease, chronicity of its course, and the average age of the males and females. The lowest blood iodine in the 5 patients with lymphatic leukemia occurred in the only patient with the acute disease, an 11 year old girl whose basal metabolic rate, nevertheless, exceeded that of the other 2 females. The blood iodine in one male with an aleukemic lymphosarcoma was, as in the patient with acute leukemia, found to be normal (table 4). In 2 other cases of lymphosarcoma hyperiodemia has been observed.[19]

Elevation of the blood iodine in lymphatic leukemia, often so definite, has previously been reported.[20] On the other hand, a normal blood iodine has been found in myelogenous leukemia.[21] K. B. Turner and his associates found the blood iodine elevated in 7 of 17 patients with lymphatic leukemia and abnormally low in 9 of 12 patients with myelogenous leukemia. The remainder had normal blood iodine values.[15b]

We observed no significant deviations in blood iodine in the other instances of blood disease under investigation, including 2 cases of Hodgkin's disease, in which an elevated level of iodine in the blood sometimes occurs,[19] 2 of splenomegaly of undetermined origin, 2 of agranulocytosis and 3 of secondary anemia (table 1). The blood iodine was high normal in 1 patient with polycythemia vera (table 4) and in 1 with pernicious anemia (table 3). Veil and Sturm observed that in pernicious anemia the blood iodine may become greatly increased during the stage of remission and subsequently decrease to normal or even subnormal during an acute crisis.[13a]

The average blood iodine was normal in 12 patients with various types of nonmalignant tumors, in 6 patients with carcinomas and in 1 with osteosarcoma (tables 1 and 4). In none of these patients was there demonstrable involvement of either thyroid or liver. With the possible exception of the blood iodine in carcinoma of the liver,[8b] the blood iodine has been generally found to be normal in cancer of nonthyroid tissues.[22]

19. Turner, K. B.; McAlpin, K. R., and De Lamater, A.: Blood Iodine in Leukemia, Proc. Soc. Exper. Biol. & Med. **39**:55, 1938.

20. (*a*) Veil and Sturm.[13a] (*b*) Curtis.[13g] (*c*) Turner, De Lamater and Province.[15b] (*d*) Turner, McAlpin and De Lamater.[19] (*e*) Curtis, G. M.; Davis, C. B., and Phillips, F. J.: Significance of the Iodine Content of Human Blood, J. A. M. A. **101**:901 (Sept. 16) 1933.

21. Turner, De Lamater and Province.[15b] Turner, McAlpin and De Lamater.[19]

22. Fowweather, F. S.: The Iodine Content of the Blood of Patients Suffering from Cancer, Brit. J. Exper. Path. **11**:400, 1930. (*b*) Kato, S.: Blutjodspiegel bei einigen chirurgischen Erkrankungen, mit besonderer Berücksichtigung der Kröpfe, Tohoku J. Exper. Med. **29**:442, 1936.

In 1 patient with osteitis deformans the blood iodine, analyzed by the dry ash method,[11] was found to be considerably elevated (table 4), while in another patient with this disease, whose blood iodine was determined by the chromium trioxide method,[12] it was considerably

TABLE 3.—*The Blood Iodine in Single Instances of Nonthyroid Disease Determined by the Chromium Trioxide Method* [12]

Clinical Diagnosis	Age	Sex	Blood Iodine, Micrograms/ 100 Cc.	Basal Metabolic Rate	Duration of Symptoms
			Above Normal + the 2 s. d. Limit *		
Rheumatic fever *	49	F	17.3	+10	3 wk.
Eczema	10	F	8.5	+ 8	10 yr.
Arteriosclerosis	69	F	8.3	....	.....
Spina bifida	49	F	8.1	— 1	49 yr.
Ringworm	34	M	7.5	—11	2 yr.
Sebaceous cyst of neck	16	F	7.1	— 8	10 yr.
Dermatitis seborrheica	30	M	7.1	+12	.....
			Between Normal and ± the 2 s. d. Limit *		
Prolapsed uterus	47	F	5.7	+27	11 yr.
Pernicious anemia	76	M	5.3	—36	1 yr.
Cystocele and retrocele	30	F	5.3	+ 7	4 mo.
Underweight	10	F	5.2	— 9	8 yr.
Hyperparathyroidism	12	M	5.1	—20	10 yr.
Subacute bacterial endocarditis	36	M	5.0	....	5 mo.
Elephantiasis cruris	32	F	4.7	— 4	11 yr.
Myositis fibrosa	41	M	4.7	....	8 yr.
Malnutrition	29	F	4.2	+18	3 mo.
Radiculitis	33	F	4.2	+ 2	4 yr.
Aortitis	45	F	4.1	+25	1 yr.
Cystitis	30	F	4.1	— 1	2 mo.
Duodenal ulcer	32	M	4.1	+ 1	4 wk.
Hypoparathyroidism	31	F	4.0	—11	6 mo.
Undescended testis	21	M	4.0	± 0	21 yr.
Chronic ulcer of leg	48	M	3.9	....	5 yr.
Osteomyelitis	13	M	3.7	—21	6 mo.
Iritis	33	F	3.6	— 7	.....
Thyreoglossal cyst	45	M	3.4	— 9	7 yr.
Osteomalacia	27	M	3.3	....	7½ yr.
Influenza	50	M	3.3	—16	"recent"
Myasthenia gravis	34	F	3.1	+22	10 yr.
Fibrous ankylosis of mandible	50	M	2.9	....	8 yr.
Appendicitis	18	M	2.8	....	6 hr.
Gastroenteritis	23	F	2.8	....	5 days
Brucellosis	53	M	2.5	+53	7 mo.
			Below Normal — the 2 s. d. Limit *		
Osteitis deformans	59	F	1.7	+15	5 yr.

* Two months after subtotal thyroidectomy for toxic nodular goiter.
† 2 s. d.: Two times the standard deviation.

reduced (table 3). The high blood iodine occurred in a man with symptoms of fifty years' duration, while the low value was noted in a female with symptoms of only five years' duration. In both patients the basal metabolic rate was elevated. These insufficient data on osteitis deformans indicate clearly the need for caution in basing deductions on

individual values alone. Such may not be representative of the whole group, especially since there may be considerable variation of the blood

TABLE 4.—*The Blood Iodine in Single Instances of Nonthyroid Disease Determined by the Dry Ash Method* [12]

Clinical Diagnosis	Age	Sex	Blood Iodine, Micrograms/ 100 Cc.	Basal Metabolic Rate	Duration of Symptoms
			Above Normal + the 2 s. d. Limit *		
Cystic arachnoiditis †	20	M	28.0	....	1 yr.
Acute serofibrinous pleurisy	16	F	24.0	....	1 mo.
Osteitis deformans	69	M	23.0	+21	50 yr.
Chronic bronchitis	10	M	20.3	—12	5-6 mo.
			Between Normal ± 2 s. d. Limit *		
Polycythemia vera	43	M	16.9	....	10 mo.
Arteriosclerotic gangrene	60	M	16.3	....	2 wk.
Hyperpituitarism	14	M	16.0	+15	.....
Lymphosarcoma	32	M	14.3	....	1 mo.
Internal hydrocephalus	31	F	14.2	— 2	1 yr.
"Hypo-ovarianism"	25	F	13.4	—10	4 yr.
Osteosarcoma	13	M	13.3	....	3 mo.
Elephantiasis cruris	24	F	13.0	—14	11 yr.
"Abnormal growth"	11	F	12.8	—13	5 yr.
"Endocrine insufficiency"	20	F	12.7	—11	4 yr.
Ruptured meniscus	18	F	12.7	....	9 yr.
Myasthenia	28	M	12.5	— 4	2-3 yr.
Ovarian degeneration, microcytic	24	F	12.3	+27	4 yr.
Idiopathic scoliosis	14	F	11.8	....	2 yr.
Bronchopneumonia	1	M	11.7	....	2 wk.
Cerebral concussion	48	M	11.2	+22	.....
Cerebral embolus	74	F	11.0	....	2 days
Glycosuria	18	M	11.0	+ 9	.....
Thromboangiitis obliterans	37	M	9.7	— 8	8 yr.
Chronic tonsillitis	30	F	9.7	— 3	.....
Osteomyelitis	30	M	9.5	....	3½ yr.
Harelip, cleft palate	8	M	9.5	....	8 yr.
Arteriosclerosis	65	F	9.3	—17	.....
Bladder stone	67	M	8.6	+ 5	1 yr.
Sciatic neuralgia	39	M	8.0	....	7 mo.
Deformity of sternum	19	M	8.0	+11	19 yr.
Duodenal ulcer	58	M	7.8	+ 2	40 yr.
Hypogonadism	18	M	7.5	—13	1½ yr.
Hyperinsulinism	44	M	7.5	....	6 yr.
Solitary bone cyst	8	M	7.2	— 7	6 yr.
Neurodermatitis	60	F	6.9	+10	.....
Tuberculosis of breast	36	F	6.6	+ 4	2 yr.
"Bone dyscrasia"	25	F	6.4	—13	2 mo.

* 2 s. d.: Two times the standard deviation.
† Iodized poppyseed oil 40 per cent was injected in spinal canal "a long time ago."

iodine in any given disease, depending on associated pathologic conditions, particularly of the thyroid gland, and the type of medication previously employed, as well as various other factors.

NONTHYROID ENDOCRINE DISTURBANCES

Our data on diabetes mellitus further illustrate the type of variation one might find in the blood iodine in any given disease. Two groups

of 3 patients each were investigated separately, because of a difference in the analytic technic employed for each case. In the more recent group the average blood iodine was normal (chromium trioxide method), whereas in a previous group (dry ash method) the average blood iodine was significantly reduced (tables 1 and 2). The average basal metabolic rates were normal in each group.

A lowered blood iodine in diabetes mellitus is consistent with the disputed [23] hypothesis of a *specific* antagonism between the thyroid and the pancreas.[24] In keeping with this hypothesis the insulin treatment for hyperthyroidism has been attempted.[24b] The rationale of this therapy obtains some biochemical support from the observation that administration of insulin may result in a decrease in the blood iodine.[13a] The inference might also follow that a low blood iodine occurring in a diabetic patient could be a result of insulin therapy.

High variability of the blood iodine in diabetes has been noted by R. G. Turner.[25] In 13 "inpatients" and 54 "outpatients" with diabetes mellitus, over one third of the total 67 had subnormal blood iodine, and almost another third had increased blood iodine values. This distribution of blood iodine levels in diabetes may parallel a similar distribution of the basal metabolic rates [26] in this disease.

The unfractionated blood iodine was normal in small groups with pituitary dwarfism, acromegaly, hirsutism, hypopituitarism, Addison's disease, "endocrine imbalance," mongolism and menstrual disturbances (table 1) and in single patients with other endocrine disorders, including hypoparathyroidism and hyperparathyroidism, hyperpituitarism, varying forms of hypogonadism and hyperinsulinism (tables 3 and 4). There were two exceptions. The blood iodine was elevated in 2 patients with Froehlich's syndrome (tables 1 and 2), despite a low but not significantly reduced average basal metabolic rate. It was increased in 1 patient with polyglandular dysfunction designated as "endocrine imbalance" (column "Dry Ash Method" in table 1).

Elevated blood iodine has been noted in the early stages of acromegaly.[27] On the other hand, in 2 patients included in this study with

23. Shepardson, H. C., and Wever, G. K.: Myxedema and Diabetes Mellitus with the Report of a Case, Internat. Clin. **4**:132, 1934.

24. (*a*) Veil and Sturm.[13a] (*b*) Lawrence, R. D.: Four Cases of Exophthalmic Goiter Treated with Insulin, Brit. M. J. **2**:753, 1924.

25. Turner, R. G.: Iodine Content of Certain Pathological Bloods in a Goitrous Region, Proc. Soc. Exper. Biol. & Med. **29**:1294, 1932.

26. Boothby, W. M., and Sandiford, I.: Summary of the Basal Metabolism Data on 8,614 Subjects with Especial Reference to the Normal Standards for the Estimation of the Basal Metabolic Rate, J. Biol. Chem. **54**:783, 1922.

27. (*a*) Perkin, H. J.: Unpublished data. (*b*) Perkin, H. J., and Lahey, F. H.: The Level of Iodine in the Blood, Arch. Int. Med. **65**:882 (May) 1940.

acromegaly present as long as eleven and nineteen years, the blood iodine was normal. Moreover, the acromegaly in 1 of these patients was accompanied by diabetes insipidus, a disease in which Blotner has observed an increased excretion of urinary iodine and a generally low normal blood iodine, both of which conditions may be altered by the administration of posterior pituitary.[28]

CERTAIN INFECTIOUS DISEASES

In most of the infectious diseases included in this series, we observed no significant elevation of the blood iodine. There were two exceptions. One was a group of 5 patients with syphilis (tables 1 and 2), among whom there was no record of iodine medication. However, 2 of the 5 patients also had hepatic damage (table 1), which may have contributed, at least in part, to the increased average blood iodine. Normal [22b] as well as elevated [18] iodine levels have been reported in syphilis.

A second group in which the average blood iodine was increased consisted of 6 males with various types of arthritis. Their blood iodine was found to differ significantly from that of 9 females with arthritis (tables 1 and 2). This difference in the average blood iodine of males and females could not be attributed to a difference in the average basal metabolic rate, which was normal in either group, or to a difference in the average age of the patients or to the duration of symptoms. Other factors, however, may be involved, such as a difference in previous medication or in the relative preponderance of a certain type of arthritis in each group. The two highest blood iodine values were found in 2 of the 3 patients with arthritis due to Neisseria gonorrhoeae, both males and 1 with accompanying syphilis. In both of these patients the elevated blood iodine diminished after fever therapy to normal levels.

The average blood iodine values of 11 patients with pulmonary tuberculosis (table 1), as is apparently also true of the urinary iodine in this disease,[29] was found to be normal. Similarly, the blood iodine was normal in 2 patients with tuberculosis of vertebra (table 1), in 1 with tuberculous cervical lymphadenitis and in 1 with tuberculosis of the breast (table 4). Nevertheless, an increase in the blood iodine has been reported in certain forms of tuberculosis.[22b] Except for the blood iodine of 1 patient with chronic bronchitis and of 1 with acute serofibrinous pleurisy (table 4), the level was found to be normal in patients with other respiratory diseases, including sinusitis, bronchiectasis (table 1) and bronchopneumonia (table 4). The blood iodine was normal in one patient with chronic empyema but elevated in another who had accompanying psoriasis.

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28. Blotner, H.: The Amount of Iodine in the Blood and Urine in Patients with Diabetes Insipidus, Am. J. M. Sc. **203**:708, 1942.

29. Klassen, K. P.; Curtis, G. M., and Hancock, R. A.: The Urinary Iodine in Pulmonary Tuberculosis, Am. Rev. Tuberc. **42**:376, 1940.

In a patient with cystic arachnoiditis, the high blood iodine noted (table 4) might be explained as a sequel to spinal injection of iodized poppyseed oil 40 per cent, although this had been performed "a long time ago." In a patient with rheumatic fever of three weeks' duration, the increased blood iodine (table 3) was more likely due to hyperthyroidism, even subsequent to a subtotal thyroidectomy two months previously for toxic nodular goiter, than to the presence of acute infection. In another patient with subacute bacterial endocarditis of five months' duration, the blood iodine was normal (table 3).

The occurrence of hyperiodemia in severe infections and in septicemia has been reported.[30] Kato found that while the blood iodine may be elevated in acute pyogenic infections and in spontaneous gangrene, it tends to be normal in chronic pyogenic infection.[22b] On the other hand, in 5 cases of acute fever Veil and Sturm found a fall rather than a rise in the blood iodine level. They thought this might be due to an increase in the tissue requirement of iodine, as well as to an increase in the urinary excretion.[13a] Fashena could find no elevation of the blood iodine level in various infectious diseases of children, including bronchopneumonia, mastoiditis, otitis media, pyelitis and cervical adenitis.[31]

CUTANEOUS DISEASES

It has long been the clinical impression among dermatologists that iodides have a tendency to cause exacerbation of acne as well as produce acneform eruptions. Further support of this idea has not been adduced from studies on the blood iodine. Thus, Traub and Emmet reported a normal blood iodine level in 45 patients with acne vulgaris.[32] Brill and Goyert could likewise find no increase in the blood iodine in 10 patients with eczema nor in 88 patients with various other dermatoses.[33] The iodine in the skin was found to be increased to about four to five times normal in 2 patients with dermatitis herpetiformis. This was correlated with a slight increase in the blood iodine. However, 6 other patients with this same disease had elevation of the iodine level neither in the skin nor in the blood. On the basis of their investigations, Brill and Goyert concluded that there is no definite relation between the blood iodine and the dermatoses, which are often accompanied by a labile sympathetic nervous system.[33]

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30. Curtis, Cole and Phillips.[13f] Curtis.[13g] Curtis, Davis and Phillips.[20e] Kato.[22b]

31. Fashena, G. J.: A Study of the Blood Iodine in Childhood, J. Clin. Investigation **17**:179, 1938.

32. Traub, E. F., and Emmet, R.: Blood Iodine of Patients with Acne Vulgaris, Arch. Dermat. & Syph. **41**:506 (March) 1940.

33. Brill, H., and Goyert, K.: Blutjodanalysen bei Hautkrankheiten und ihre Beziehungen zum vegetativen Nervensystem, Arch. f. Dermat. u. Syph. **180**:63, 1940.

We have insufficient data to draw any conclusions with respect to the blood iodine in cutaneous diseases. However, it may be of some significance that in the few instances of a cutaneous disease under investigation (table 3), with the exception of that of neurodermatitis (table 4), the individual blood iodine values were elevated. These diseases, each represented by a single patient, are: eczema, ringworm, sebaceous cyst of the neck and dermatitis seborrheica. The basal metabolic rates were within normal limits,[1b] ranging from minus 11 to plus 12 per cent. In 1 patient with empyema of six years' duration, with associated psoriasis, the blood iodine was greatly elevated, being almost twice as high as that in another patient with an uncomplicated empyema of two years' duration.

PSYCHIC AND NERVOUS DISTURBANCES

We noted no significant variations of the blood iodine in any of our patients with psychic or nervous disturbances. These included chiefly 19 patients with psychoneurosis, 9 with neurasthenia and 30 with "functional" disorders (table 1). In 3 patients with vagotonia (table 1), we found a low normal blood iodine, which was accompanied in 2 of the 3 by low basal metabolic rates of minus 20 and 29 per cent. The latter was the average of three determinations made on three different occasions within a period of six months. During the six months the basal metabolic rate of this patient, as well as the blood iodine, steadily declined, the blood iodine to half its original normal value.

Veil and Sturm reported a lowered blood iodine in patients with vagotonia.[13a] Perkin and Lahey maintained that the blood iodine levels in normal persons of a vagotonic type fall within the lower normal range, whereas they lie within the upper normal range in those of a sympathicotonic type.[27b] The blood iodine may be increased after stimulation of the nervous system or on the injection of epinephrine.[13a] The subcutaneous injection of epinephrine apparently has no effect on the blood iodine of hyperthyroid patients, but will cause a rise in the "organic fraction" of normal persons.[34]

Neustadt and Howard have observed that among the psychoses the blood iodine level deviates from the normal only among the *true* manic-depressive types, being high in the manic group (47 patients) and low in the depressive group (30 patients). There is a close parallelism between the level of the blood iodine and the manic-depressive changes in mood, but no parallelism between the blood iodine and change in motor excitement of these patients. On the other hand, the blood iodine is remarkably constant in patients with dementia paralytica, paranoia or schizophrenia,

34. Gutzeit, K., and Parade, G. W.: Blutjodstudien: XI. Die Beeinflussung der Blutjodverhältnisse durch Adrenalin, Ztschr. f. klin. Med. **135**:183, 1938.

even despite changes in mood.[35] K. B. Turner and his associates could find no elevation of the blood iodine in 6 neurotic females.[15b]

SUMMARY

The iodine concentration in the whole blood of representative patients with 115 different nonthyroid diseases was determined. The findings are presented, tabulated and discussed. A review of the pertinent literature is included.

It should be remembered that the groups studied were small and thus our results may not signify the general trend of the blood iodine levels in the disease, but rather types of variation which may occur. Moreover, it cannot be implied at this time that these variations are due to the disease itself rather than to other concomitant factors.

The average concentration of iodine in whole blood was found to be, with few exceptions, consistently normal in patients with nonthyroid diseases. Nevertheless, there are those instances in which certain pathologic processes may be associated with an increase of the blood iodine. These merit further investigation. They include, more so in this study, cholecystitis with cholelithiasis, and less frequently, essential hypertension and hypertensive cardiac disease. High elevations may sometimes occur in patients with lymphatic leukemia, and these are accompanied by increased basal metabolic rates. In some instances, for example in essential hypertension, a high level of iodine in the blood may perhaps be due to the type of medication or to an accompanying thyroid involvement.

Abnormal increase and even decrease in the blood iodine may also occur in patients with certain other nonthyroid diseases. These observations are especially difficult to evaluate owing to the scarcity of available data. Among such diseases are only a few of the many nonthyroid endocrine disturbances, certain infectious disorders and possibly, although questionably, certain diseases of the skin.

We found little evidence of any deviation from the normal of the average iodine level in whole blood in certain diseases of a psychic or neurogenic character. This was likewise true for myelogenous leukemia and for neoplasms, both benign and malignant, of neither thyroid nor hepatic origin.

In the nonthyroid diseases in which an elevation of the average level of iodine in the blood occurred, an increase in the basal metabolic rate was not always apparent.

35. Neustadt, R., and Howard, L. G.: Fluctuations of Blood Iodine in Cyclic Psychoses, Am. J. Psychiat. **99**:130, 1942.

CONGENITAL HYPERTROPHIC PYLORIC STENOSIS

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CONGENITAL hypertrophic pyloric stenosis is the most common condition requiring surgical treatment in the infant. Although it was first described by Fabricus Hildanus in 1627, intelligent interest in the abnormality did not develop until 1887, when Hirschsprung gave a convincing description of the disease. The application of surgical measures to its correction dates back to 1892, when Cordua, of Hamburg, performed jejunostomy, unsuccessfully. Subsequently, various operative procedures were tried, gastrojejunostomy being the operation most commonly employed. This carried a disturbing mortality of approximately 50 per cent. In 1907 Pierre Fredet performed what amounted to a Heineke-Mikulicz pyloroplasty in 2 cases. In 1911 Rammstedt, when confronted with unusual difficulty in closing the muscle in that type of operation, sutured the omentum over the protruding mucosa, with successful results. Thus, pyloromyotomy, which is now employed, was evolved somewhat by accident and necessity.

Even though the operation is simple and almost foolproof, the results are so gratifying, and at times spectacular, that the surgeon usually takes great pride in its successful accomplishment. Although cases of this anomaly are now seen rather commonly, I thought it might be of interest to this group of general surgeons to discuss the experiences of my colleagues and myself with a series of 129 infants on whom operation has been performed during the past twenty-four years.

My interest in this problem has been stimulated by Dr. R. R. Hippensteel, a pediatrician in Indianapolis, who concluded early in his practice that this was a surgical condition and gave up the long, tedious course of medical management, then too often employed. He insisted then, as now, that infants with this anomaly were best served by pyloromyotomy when the diagnosis was once established. A majority of the infants in this series were his private patients, and because of my interest in this problem the series includes patients referred by a number of other pediatricians. Twenty of the patients were operated on in the charity hospitals; the other 109 were private patients. All these patients were cared for in cooperation with a pediatrician. The care of the infant is so different from the care of the average surgical patient

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that I believe the pediatrician should play a prominent role in the care of all infants requiring surgical treatment. The problems of diagnosis, preoperative preparation and postoperative feeding of these babies were directed for the most part by pediatricians. The observations expressed here include the views of those associated with me in the care of these babies.

ETIOLOGIC FACTORS

Little is known of the cause of this condition, but it is generally agreed that the tumor develops before birth and that the onset of symptoms occurs when spasm and edema are superimposed on partial obstruction. It occurs predominantly in the male and in the first born. In the present series there were 109 males and 20 females, a ratio of 5.5:1. Approximately one-half the patients were first-born children,

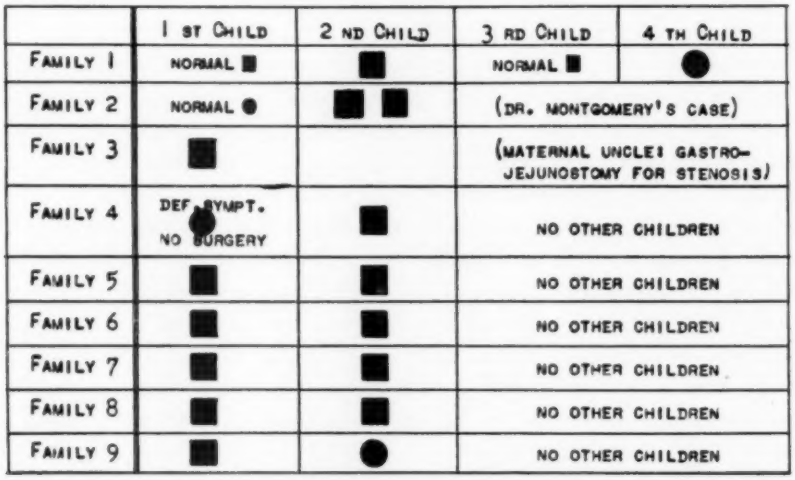

Fig. 1.—Heredity as an etiologic factor in congenital pyloric stenosis, as illustrated by its occurrence in more than 1 sibling—each of nine families. In this chart, affected boys are indicated by black squares; affected girls, by black circles, and twin boys by two black squares.

but since families of private patients are small it is difficult to state that this incidence is of much significance.

Heredity seems to be an important etiologic factor. In this series there were 6 instances of 2 affected members in one family. In 4 cases these were the first 2 boys of the family; in the fifth case the older patient was the first-born male child and the other was the second child, a girl. In the sixth case the older was the second child and the younger was the fourth child, a girl. One patient was the first-born male infant, whose mother's brother, a first-born child, had had a successful gastrojejunostomy for stenosis in Cincinnati in 1914.

Another male infant with stenosis had an older sister who had all the symptoms of a stenosis, with which she had lived without surgical intervention, although not too well. She had vomited a great deal until

she was 3½ years of age and was a frail child. We felt that she undoubtedly had had a partial stenosis. Recently, I saw twins, not identical, which were operated on by Dr. W. F. Montgomery on the same day for stenosis.

Cockayne and Penrose, in London, studied this problem in 212 cases and concluded that the underlying cause of congenital pyloric stenosis is the possession of a pair of abnormal genes, one received from each parent. They stated that should the recipient chance to be a boy and the first born, he will almost certainly have this abnormality. A subsequent child or any daughter, even though she is the first born, is more likely to be normal than affected. They stated that the chances of the second child's being affected is not more than 1 in 20.

DIAGNOSIS

The symptoms usually mentioned are projectile vomiting, constipation, gastric contraction waves, loss of weight, dehydration and a palpable tumor. Of these, projectile vomiting and gastric contraction waves are, in our opinion, the most important. Although some authors have stated that they can feel the tumor in almost all cases, we felt it in less than 50 per cent of our patients and doubt whether it can be felt in a majority of babies when they are in a fair state of nutrition. Since the tumor can be felt in only a small proportion with any degree of certainty, we doubt the advisability of repeatedly disturbing the baby by the manipulations required to find it. Usually, about the second or third week the baby starts to spit up a small amount of its feedings and at a variable time later begins to have real projectile vomiting. Then in the epigastrium, especially after the feedings, strong gastric waves appear, passing from left to right. These often cause the infant pain and usually are followed shortly by vomiting. The baby is then placed on Sauer's thick cereal feedings [1] for at least forty-eight hours. Barbiturates may be used as a sedative, and atropine has been employed occasionally. If the infant continues to vomit the greater portion of its feeding and has the characteristic gastric contraction waves, the diagnosis is established. A danger of the thick cereal feeding is that if there is still an obstruction the baby is dehydrated rapidly and becomes a poor risk if surgical intervention is delayed too long. Therefore, the child must be watched carefully. When we have been in doubt, we have sometimes submitted the baby to a roentgenologic examination with a thin barium sulfate meal. It is our conclusion that this is not very helpful. On a few occasions the roentgenologist did not discover a stenosis when it was present, and on others he made a diagnosis of stenosis when the condition was pylorospasm. Moreover, it is diffi-

1. The formula is as follows: Skimmed milk, 9 ounces; water, 12 ounces; farina or rice flour, 6 teaspoons; dextrimaltose, 3 ounces.

cult to remove the barium sulfate from the stomach, even with lavage, adding to the hazards of aspiration of this material when the baby vomits. Few babies now are given a barium sulfate meal.

The most difficult problem is to differentiate this condition from pylorospasm. In pylorospasm the vomiting is not so persistent and may be intermittent. The child does not become dehydrated or lose weight so rapidly and seems tenser. Yet I must confess that even with every diagnostic aid, including the roentgenogram, I have operated on a few babies, both in charity and in private hospitals, in whom no stenosis or other surgical pathologic condition was present. In several cases the roentgenologic diagnosis was conclusive, with almost complete retention of the barium sulfate after four hours. Although this fact is seldom reported, I am certain that every surgeon operating often for this anomaly will encounter about 1 case in 20 in which no stenosis is present. In such cases I have dilated the pylorus well and the babies have usually improved, although not so spectacularly as those with true stenosis. The average age of the infants with stenosis, at the time of operation, was between 5 and 6 weeks. The youngest baby was 13 days and the oldest 5 months of age.

SURGICAL PROCEDURE

The baby is prepared for operation by giving it subcutaneous injections of isotonic solution of sodium chloride, 10 cc. per pound (45 Gm.) of body weight every eight hours, as indicated. These are usually given while the baby is under observation, when he is taking the thick cereal. When the baby is in a poor state of nutrition, he is given similar amounts of blood in one or more transfusions. In recent years, the babies are in better condition and fewer need transfusions. If the baby has had a barium sulfate meal recently, the stomach is lavaged with a small tube before operation. I have employed general anesthesia in approximately 85 per cent of the babies but have used 0.5 per cent procaine hydrochloride by infiltration with babies who are considerably under par and are poor surgical risks. When local anesthesia is used, 1 grain (0.065 Gm.) of phenobarbital is given rectally one-half hour before operation as a sedative, and a sugar teat is used to pacify the baby during operation. For general anesthesia, I almost always use ether, but in 8 cases Dr. F. A. Thomas, chief anesthetist at St. Vincent's Hospital, has given cyclopropane. He states that he has given almost 100 infants cyclopropane for various surgical procedures and is enthusiastic about its use. I much prefer ether but have permitted Dr. Thomas to use cyclopropane because of his skill and his enthusiasm for it. In these few cases it has proved to be a very satisfactory anesthetic.

The actual surgical procedure is simple, but there are a few points which I consider important. The baby should be strapped on a special board and prepared as the anesthetic is started. The anesthesia should

be as short as possible and only sufficient in amount to quiet the baby. A suction machine should always be in the hands of the anesthetist to prevent any aspiration of vomited material, particularly when the patient

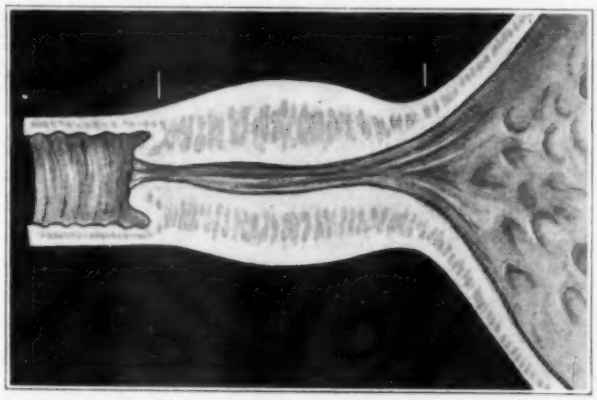

Fig. 2.—Longitudinal section of the stomach in a case of congenital pyloric stenosis, showing the abrupt manner in which the tumor ends at the duodenum.

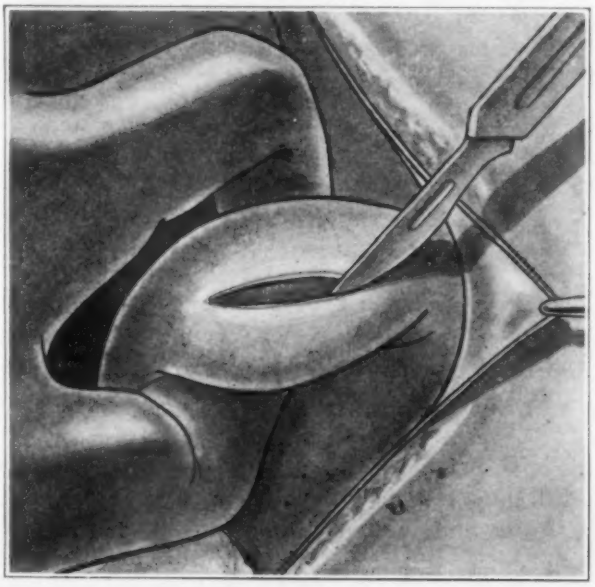

Fig. 3.—Division of superficial layers by sharp dissection.

has had a barium meal. We almost lost a baby when this precaution had been overlooked. I have tried other types of incision, but I prefer a high short right rectus incision. The main requirement of the incision is that it be small. The average surgeon, who is accustomed to operating on adults, makes too large an incision. It need be only large

enough to permit one to introduce the finger and then deliver the tumor. An incision 1 to 1½ inches (2.5 to 3.7 cm.) in length is usually sufficient. The tumor is delivered by gentle traction on the stomach and is held with the left hand. The tumor is incised on the anterior surface through approximately one-half its thickness and then is split by using the handle of the scalpel, especial care being taken at the duodenal end of the tumor. There have been reports of many instances in which the duodenum was opened at this point, a possibility which constitutes the main hazard of the procedure. Ladd and his associates [2] reported 14 such accidents among 763 cases, in all of which closure was made carefully, but there were 3 fatalities. Figure 2 illustrates the anatomic condition that makes it easy to enter the duodenum at

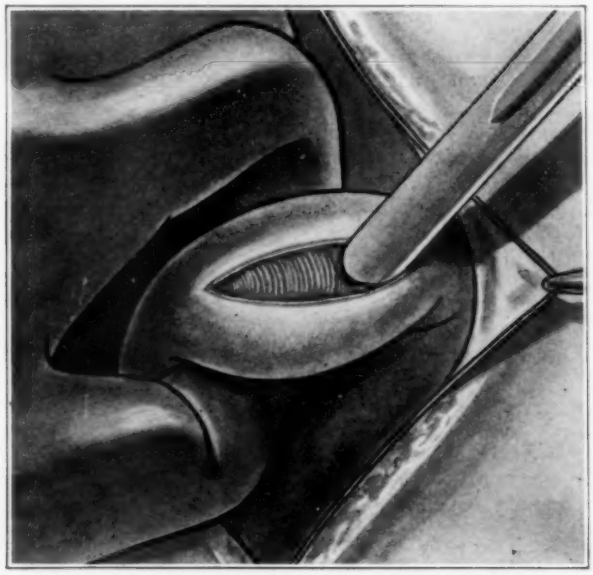

Fig. 4.—Division of deep fibers with the handle of the scalpel.

this point. I have practiced spreading the tumor widely and carrying the division well up onto the stomach, but leaving some of the transverse fibers at the lower end undivided over the point where the mucosa forms a pouch and is very thin. Thus, injury to the duodenum has been avoided, and the results have been entirely satisfactory. Bleeding usually requires no attention other than pressure for a moment. Occasionally a small vessel needs to be tied, and this is best done by passing a fine suture or an atraumatic needle around it. The use of a hemostat to grasp the vessel is usually futile because the tissue is fragile and easily tears. The wound is closed in layers with fine chromic surgical

2. Ladd, W. E., and Gross, R. E.: Abdominal Surgery of Infancy and Childhood, Philadelphia, W. B. Saunders Company, 1941.

gut and silk. A small gauze dressing, of sufficient size just to cover the wound, is strapped tightly with adhesive tape.

After operation, it is important to see that the baby does not aspirate its vomitus before it recovers from the anesthesia. Feeding is begun two hours after operation. Various formulas have been used, all employing the principle of starting the feedings early and giving small amounts frequently. One-half ounce (14 cc.) of a diluted milk formula is given every two hours for the first twenty-four hours, with one-half ounce of plain water or 5 per cent solution of beta lactose on the alternate hours. After twenty-four hours the amount of each is increased as tolerated.

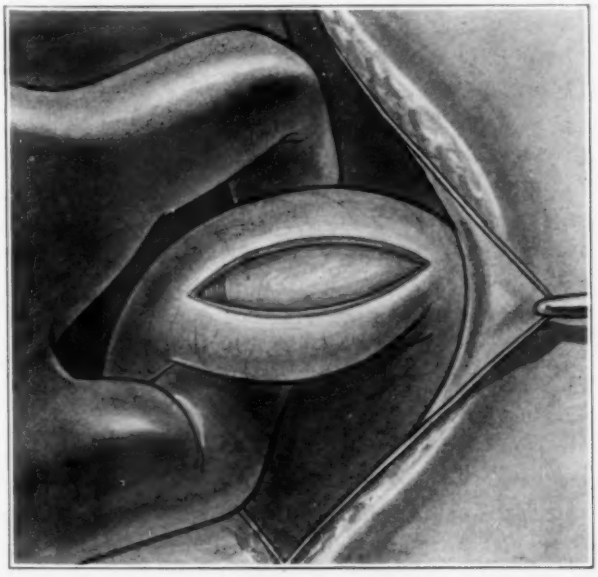

Fig. 5.—A few fibers at the duodenal end not divided but with separation carried well onto the stomach.

The baby is given a small dose of barbiturate if it is restless and subcutaneous injections of isotonic solution of sodium chloride if it seems dry. However, we feel that these babies should not be overtreated and that they do better if they are allowed to recuperate with the minimum amount of subcutaneously administered fluids. The average stay of the baby in the hospital after operation is six to seven days.

I have had no case of wound separation or evisceration. Approximately 10 per cent of the wounds have had drainage, varying from a small amount of serum, in most cases, to moderate infection, in a few cases. I believe this is because the wound in the undernourished infant does not heal so well as in the adult. No serious complications have resulted from the drainage.

I have operated on 129 babies, with 2 deaths. One death was that of a premature child weighing 3 pounds (1,360 Gm.) at birth; the infant was in an incubator for more than one month, and at three months it weighed 4 pounds (1,814 Gm.), when the diagnosis of a stenosis was made. It survived operation and was doing nicely until an obstruction of the small bowel developed on the tenth postoperative day, causing the infant's death. The second death was that of a baby who did well after operation and was taken to its home in a neighboring city. It was brought back six weeks later in a terrible state of malnutrition, with recurrence of its stenosis. It was prepared with blood transfusions and subcutaneous administration of fluids and was reoperated on. A small, threadlike, firm band, 1 mm. in diameter, was observed at the pylorus, completely closing the lumen. This was divided, but the child did not survive. It has been unnecessary to reoperate on any of the other infants, but in this series were 2 babies who had been operated on elsewhere, two weeks and one month respectively, before and the tumor had been insufficiently divided or the fibers had reunited. In each case the infant recovered after more complete division of the tumor. I believe that when a secondary operation is necessary it is because there was incomplete division of the tumor, and not because the fibers have reunited. In my case, I feel certain that a few strands of the transverse fibers were overlooked and not divided and that these fibers hypertrophied and caused the subsequent recurrence. Since that time, I have carefully divided all such fibers.

Various observers state that this hypertrophied tissue disappears in a relatively short time after it has been divided. One of the babies who had completely recovered from the stenosis died three months later, of an unrelated acute infection. Postmortem examination revealed that the pylorus was normal, with a small tab of omentum adherent to the scar. In the baby operated on again after six weeks there was no evidence of disappearance of the tumor, although it had been well divided except for the small band. I did an appendectomy on another child eight years after the operation for stenosis and observed that the pylorus was normal.

END RESULTS

There were 2 deaths among the 129 infants in this series. The other babies have done remarkably well. Some regurgitated a small amount of their feedings for a short time, but I know of no other simple surgical procedure that has produced such immediate relief of symptoms and such permanently satisfactory end results as pyloromyotomy for stenosis in infancy. I doubt the advisability of treating medically any infant with stenosis when surgical relief is so simple and satisfactory. The infants for whom medical management has been tried, and who have required operation at the age of 3 months or more, have often been poor surgical risks.

SUMMARY

Pyloromyotomy for stenosis in infancy is a simple operation that should carry a very low mortality if not delayed too long and if the baby is properly prepared. The end results are extremely gratifying. I have operated on 129 infants, with 2 deaths, 1 of which could have been avoided. Of these infants, 109 were males and 20 females. Approximately one-half were the first born of the family.

That heredity is an important etiologic factor is indicated by the frequency with which more than 1 case has occurred in the same family.

The diagnosis can be established by observing projectile vomiting and strong gastric contraction waves following the use of thick cereal feedings over a short period. It is doubtful whether roentgenologic examination is of much value, and a barium sulfate meal should be avoided except when there is an unusual problem in diagnosis.

I have been unsuccessful in feeling the tumor in the majority of cases and doubt whether its palpation is necessary to establish the diagnosis.

Babies with this defect are small and should be handled gently. Light ether anesthesia is the most satisfactory form in the majority of cases.

The abdominal incision should be small. Special care should be taken at the duodenal end of the tumor to avoid injury to the mucosa by leaving a few transverse fibers, with the incision carried well onto the stomach.

The diagnosis and major portion of the preoperative and postoperative management should be entrusted to a competent pediatrician.

A group of pediatricians, particularly Dr. R. R. Hippensteel, referred the majority of these babies to me and directed the major portion of their care.

822 Hume Mansur Building.

DISCUSSION

Dr. John E. Owen, Indianapolis: Dr. Nafe has completely covered the subject of congenital hypertrophic pyloric stenosis and has given us his experience with this clinical entity, so that any discussion can be only a summarization of his points and a consideration of minor technical points. The surgeon who has a well qualified pediatrician to make the diagnosis, prepare the patient for surgery and arrange for postoperative management need be concerned only with the surgical technic.

In Indianapolis, my colleagues and I feel that this portion of the problem is well under control. Our problem is to perfect our professional measures. The most important technical points are as follows:

1. Proper restraint of the patient is essential. The use of a well padded splint and light weight towels assure the surgeon a stationary field for operation.

2. Use of local anesthesia supplemented with a sugar teat will avoid the complication of aspiration and in our hands has been adequate.

3. A high right rectus incision, splitting the transversus fibers, will prevent postoperative evisceration, especially if placed high enough to require retraction of the liver. Such an incision will also avoid being too large, a criticism which Dr. Nafe has made. It will admit one finger only.

4. Fine curved intestinal needles should be used as tractors to pick up the stomach and deliver the tumor. Handling with forceps should be avoided, as it will delay the return to normal peristaltic activity.

5. After the tumor has been split, the parts must be spread apart, so that submucosa bulges well into the defect. Several recurrences, requiring a second operation, have seemed to arise from failure to do this.

6. A fine silk suture is used to control any bleeding from the transpyloric vessels. Failure to recognize the possible seriousness of such bleeding resulted in our only fatality. Compression on the surface of the tumor with forceps is unreliable, and a suture ligature is safe.

7. Recognition of the danger of trauma to the duodenum is important. The best measure to prevent such trauma is care in not extending the serosal incision over the duodenal margin. If injury does occur, closure of the defect with an omental patch sutured in place will suffice to control the situation.

8. Passage of a catheter through the esophagus into the stomach will deflate this viscus and permit of easy return to the abdomen.

9. Careful closure with fine suture material completes our technic. Dr. Nafe's skill, as demonstrated by his report, can well be envied. The points I have enumerated helped us to maintain satisfactory results and to reduce our complications.

Dr. George B. Packard Jr., Denver: The operation for congenital pyloric stenosis, while it was simplified to a great extent by the Rammstedt procedure, still carried a rather high mortality rate for a number of years. This mortality was the result of two factors: First, all babies with this defect were kept as medical patients and were referred to the surgeon only as the last resort, so that he had to deal with a starved and dehydrated infant. Second, when the surgeon received such a patient, he considered that the starving infant needed emergency treatment and operated immediately, without proper restoration of the fluid and electrolyte balance.

Like Dr. Nafe, we have found no disadvantage in a high right rectus incision after the patients have vomited only one or two weeks, and it is our practice, as it is his, to see that they receive sufficient fluids and electrolytes parenterally. It is our custom to give practically all these patients either plasma or blood intravenously, before or during or after operation.

One or two points may be mentioned. We do not feed these babies for forty-eight hours after the surgical procedure. We feel that they should be treated like any other patient whose stomach has been handled; the stomach is not ready for food, and if sufficient nourishment can be given intravenously we do not feed them. My personal series of cases is now about 140, and in the last 88 cases there has been no fatality.

Occasionally one of these patients shows bleeding from the stomach before or after operation, even though the stomach has not been opened. It was thought for a while that this might be due to a vitamin K deficiency; but the prothrombin time was determined in a number of consecutive cases, and we were not able to find any increase.

I should like to mention 1 case, that of a boy aged 7½ weeks who came to the Children's Hospital with a history of having had a typical Rammstedt operation eighteen days before for congenital pyloric stenosis. The physician stated that the baby had done very well for a week and then had begun to vomit again and show typical signs of obstruction and had lost all he had gained.

It was planned at operation to expose the pylorus again and to lengthen the incision or divide whatever fibers had not been sectioned, but at operation the

pylorus could not be exposed. It was involved in adhesions and inflammatory tissue; so a posterior gastroenterostomy was performed. This operation had at first been the standard procedure for this abnormality, but it was followed by a prohibitive mortality. The child made as good a recovery as that which follows the ordinary Rammstedt procedure; we felt therefore that a properly prepared infant could stand a gastroenterostomy as well as a Rammstedt pyloroplasty.

Like Dr. Nafe, we have found no disadvantage in a high right rectus incision with splitting. In making the closure, we do not suture the fascia as a separate layer or bury any material. We employ a fine surgical gut for the peritoneum and use either two or three silk figure 8's which include the skin and fascia; and in that way we have no foreign material except in the peritoneum. The incisions seem to heal more kindly. I congratulate Dr. Nafe on his fine results and his excellent presentation.

Dr. John J. Ireland, Chicago: At the Children's Hospital in Chicago in the last ten years, my colleagues and I have performed operation for pyloric stenosis on 260 patients. There have been 2 deaths in this series, a mortality of 0.7 per cent. Of the 2 deaths, 1 occurred about twelve hours and the other about fourteen hours after the operation. On 1 patient autopsy was performed, revealing a tremendous dilatation of the right side of the heart; on the other no autopsy was held; so the cause of death was not known.

Among the last 109 patients—in other words, all those operated on since 1943—there were no deaths. I should like to ask the speaker what method of closure he would use if he accidentally perforated the duodenum.

Doty, in 1944, reported a method in which if he perforated the duodenum or opened the duodenum he closed the primary incision immediately and then turned to a new place in the tumor and made a new incision and carried out the same type of operation again.

In our hospital, emergency operations are not performed on infants with this defect. The patients are kept long enough to be hydrated before the operation is done, and some of them are given blood transfusions. In every case in the last ten years, I think that a tumor has been felt before the operation.

Dr. Cleon A. Nafe, Indianapolis: I wish to thank the discussants for their contributions to this subject. One of my anesthetists has often remarked at the close of this operation, "You aren't going to charge for that little job, are you?" In other words, the procedure is not an extensive one.

The last discussant asked what I should do if I accidentally opened the duodenum. I had always thought that the proper procedure would be to suture a portion of the omentum to the opening, at the same time closing it with a very fine suture. That was the procedure first used by Dr. Rammstedt when he devised the operation now employed so widely.

I appreciate the fact that my end results have been good because our pediatricians are convinced that babies with this defect should be operated on early. They have prepared the infants well, and as a result the mortality has been especially low. There should be no mortality in these cases except in that occasional case of neglect through the family's failure to see a good pediatrician or refusal to permit operation.

As I previously stated, I have no objection to the use of blood transfusions; I use them in cases of serious neglect. I do feel that traumatizing the baby in trying to get into the veins retards recovery unnecessarily, especially when the infant is in fairly good condition. I allow the baby to get well as rapidly as possible on his own power when the condition has been corrected surgically, by giving him the minimum amount of artificial injections indicated, and I find that the powers of recovery of these infants are usually remarkable.

PROGRESS IN ORTHOPEDIC SURGERY FOR 1945

A Review Prepared by an Editorial Board of the Amercian Academy of Orthopaedic Surgeons

XIII. NEUROMUSCULAR DISORDERS EXCLUSIVE OF POLIOMYELITIS

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DURING 1945 there has been still greater increase in the amount of literature dealing with neuromuscular disorders, especially cerebral palsy. Literature in the field of neuromuscular disorders exclusive of poliomyelitis is apparently coming to deal more and more with study in distinguishing between the pyramidal and the extrapyramidal tracts. The material can be considered under the following headings: (1) cerebral palsy, (2) paralysis of other types, (3) muscle disorder, (4) muscular atrophy, dystrophy and syringomyelia and (5) traumatic conditions of the nerves.

A paper by Kennard and Welch [386] of an experimental nature utilizing monkeys and chimpanzees, is of great importance with regard to distinguishing between different types of damage to the cortex and in differentiation between areas 4 and 6. Removal of area 6 is followed by spastic paresis, while removal of area 4 is followed by paresis without spasticity. Removal of the postcentral gyrus caused transient flaccidity. Also, the removal of areas 4 and 6 together resulted in immediate spastic paresis. This is of importance in distinguishing upper motor neuron flaccidity, which has been known to exist in spastic paralysis for years, and lower motor neuron flaccidity.

A paper by Lassek [387] discusses the relationship of the Babinski sign to the pyramidal syndrome and shows that the sign is not necessarily consistent in all these patients. Victor Gonda [388] discusses signs of pathologic changes in the pyramidal tract and describes their use. He includes among these the Babinski sign and the various modified technics such as the technics of Chaddock, Oppenheim and Gordon. The Rossolimo sign and the Hoffmann sign are also described. Others are

386. Kennard, M. A., and Welch, W. K.: Relation of Cerebral Cortex to Spasticity and Flaccidity, Tr. Am. Neurol. A. **70**:158-164, 1944.

387. Lassek, A. M.: Human Pyramidal Tract: Correlation of Babinski Sign and Pyramidal Syndrome, Arch. Neurol. & Psychiat. **53**:375-377 (May) 1945.

388. Gonda, V. E.: Pathologic Pyramidal Tract Signs: Elicitation, Interpretation and Evaluation, M. Clin. North America **29**:45-61 (Jan.) 1945.

mentioned which are of value in showing disturbances of the pyramidal tract.

Lubin [389] contributes a discussion of the pyramidal tract as regards anatomy, histology, relationship and function. Thorne [390] also discusses the pyramidal tract, from the point of view of developmental studies and types of associated diseases.

Rutherford discusses the cause of extraneous movements in spastic paralysis [391] and also makes a comparative study of the speech in children with cerebral palsy.[392] He evaluates the speech on the basis of loudness, pitch, rate, rhythm and quality.

Odoroff [393] discusses the occupational background of cerebral palsy in the parents of children with cerebral palsy.

Pick and Unna [394] describe effects of experiments with curare and curare-like substances in the central nervous system. They conclude that crystalline d-tubocurarine chloride dihydro-beta-erythroidine hydrochloride, quinine ethochloride, nicotine and thiamine inhibited and suppressed the electrical activity of the frog brain. Neostigmine failed to influence the effect of these substances on brain potentials. They conclude that the mechanism is an inhibition of central synaptic transmission.

Lieutenant Commander Harvey E. Billig Jr. [395] discusses reinnervation of muscles by neurotripsy. In the open surgical method this is carried out by compressing the nerve branches with a small hemostat sufficiently to interrupt the enclosed axons, without disrupting the sheath. In the closed method, a blunt instrument is kneaded through the muscle vigorously, deeply and repeatedly throughout its entire area. Attempt is made to spread the muscle apart in as many places as possible. The factors necessary to be considered in analysis of nerve-muscle function are described, and it is important that reeducation of muscles for further function should be carried out.

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389. Lubin, A. J.: Relationship and Function of Pyramidal Tract, Am. J. M. Sc. **209**:111-127 (Jan.) 1945.

390. Thorne, F. C.: Developmental Studies of Pyramidal Spasticity, Am. J. Ment. Deficiency **49**:43-52 (July) 1944.

391. Rutherford, B. R.: Extraneous Movements in Cerebral Palsy, Physiotherapy Rev. **25**:63-67 (March-April) 1945.

392. Rutherford, B. R.: Comparative Study of Loudness, Pitch, Rate, Rhythm and Quality of Speech of Children Handicapped by Cerebral Palsy, J. Speech Disorders **9**:263-271 (Sept.) 1944.

393. Odoroff, M. E.: Occupational Background of Cerebral Palsy, Am. J. Ment. Deficiency **49**:369-372 (Jan.) 1945.

394. Pick, E. P., and Unna, K.: Effect of Curare and Curare-Like Substances on Central Nervous System, J. Pharmacol. & Exper. Therap. **83**:59-70 (Jan.) 1945.

395. Billig, H. E., Jr.: Muscle Reinnervation, J. Internat. Coll. Surgeons **7**: 457-461 (Nov.-Dec.) 1944.

Two papers, one by Holmes, Highet and Seddon [396] and the other by Parkes,[397] contribute to the already extensive literature regarding ischemic contracture with special reference to Volkmann's contracture.

Chandler [398] discusses isolated paralysis of serratus anterior muscle from the point of view of cause and treatment, with 4 reports of cases. Badolle [399] also describes isolated paralysis of the serratus magnus.

Rosen [400] discusses abnormalities of the brachial plexus of traumatic origin in paratroopers, and Toft [401] discusses brachial paralysis in general, with special reference to obstetric paralysis of the upper extremities.

Peacher and Robertson [402] discuss the causes of, and neurologic complications in, paralysis following the use of typhoid vaccine.

Burdick, Whipple and Freeman [403] discuss amyotonia congenita (Oppenheim's disease) with reports of cases, histologic studies and description of the exact physical findings to be expected. They conclude that it is thought to originate from a developmental defect of the Betz cells in the motor cortex and the anterior horn cells of the spinal cord.

Cerebral Palsy.—In the field of cerebral palsy it is obvious that there are many complications requiring treatment besides complications affecting the locomotor system alone.

McKibben [404] points out the various complications in speech which require consideration. Her article is based on her own experience as a child. She discusses the effect of environment on the ability of a person with cerebral palsy to speak. There are many different speech disturbances she considers.

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396. Holmes, W.; Highet, W. B., and Seddon, H. J.: Ischemic Nerve Lesions Occurring in Volkmann's Contracture, Brit. J. Surg. **32**:259-275 (Oct.) 1944.

397. Parkes, A. R.: Traumatic Ischemia of Peripheral Nerves, with Some Observations on Volkmann's Ischaemic Contracture, Brit. J. Surg. **32**:403-414 (Jan.) 1945.

398. Chandler, F. A.: Isolated Paralysis of Serratus Anterior Muscle, S. Clin. North America **25**:21-27 (Feb.) 1945.

399. Badolle, R.: Paralysie du nerf du grand dentelé, Lyon chir. **37**:156-158, 1941-1942.

400. Rosen, V. H.: Traumatic Neuropathy of Brachial Plexus in Paratroopers, Bull. U. S. Army M. Dept., January 1945, no. 84, pp. 121-122.

401. Toft, G.: On Obstetric Paralysis of Upper Extremities (Erb-Duchenne and Klumpke's Brachial Plexus Paralysis), Acta orthop. Scandinav. **13**:218-270, 1942.

402. Peacher, W. G., and Robertson, R. C. L.: Neurological Complications Following Use of Typhoid Vaccine, J. Nerv. & Ment. Dis. **101**:515-526 (June) 1945.

403. Burdick, W. F.; Whipple, D. V., and Freeman, W.: Amyotonia Congenita (Oppenheim): Report of Five Cases with Necropsy; Discussion of Relationship Between Amyotonia Congenita, Werdnig-Hoffman Disease, Neonatal Poliomyelitis and Muscular Dystrophy, Am. J. Dis. Child. **69**:295-307 (May) 1945.

404. McKibben, S.: Spastic's Speech Situation, Quart. J. Speech **31**:358-362 (Oct.) 1945.

Rutherford [405] discusses hearing loss in palsied children as measured by the audiometer. He points out that there is a greater percentage of hearing loss in the patients with extrapyramidal disorders.

Berger [406] in an enlightening paper entitled "Subjective Observations on Cerebral Palsy," discusses many phases of the condition from his own experiences.

Palmer and Zerbe [407] have an interesting paper on the control of athetoid tremors and sound stimuli of different types. This is an extensive paper and of considerable value.

Wagley [408] discusses the characteristics of spasticity unassociated with paralysis in experiments on the Macaca mulatta. He points out that there is an intimate functional and anatomic relationship between the corticofugal systems from area 4s and the reticulospinal tracts. This paper is of great interest in connection with the origin of spasticity in the cortex.

Norfleet [409] has prepared a general article for technicians which enumerates various reflexes, including tendon reflexes, sucking reflexes, abdominal reflexes and cremasteric reflexs. The pyramidal and extrapyramidal systems are discussed briefly, as are the cause of cerebral palsy and its treatment by education.

In another article Norfleet [410] discussed the psychologic background for the education of children with cerebral palsy.

Jennings [411] has written an article designed to acquaint the general public with some of the fundamental problems of cerebral palsy. It describes the therapeutic day nursery at the Michael Reese Hospital in Chicago in some detail.

O'Brien [412] describes the types of disorders of patients under treatment and study at the Department for the Correction of Motor Disabilities of the Neurological Institute in New York. There is one group of 18 who have five treatments a week and special educational facilities. The second group, of about 100, come in for treatment

405. Rutherford, B. R.: Hearing Loss in Cerebral Palsied Children, J. Speech Disorders **10**:237-240 (Sept.) 1945.

406. Berger, C. C.: Subjective Observations on Cerebral Palsy, J. Speech Disorders **10**:297-302 (Dec.) 1945.

407. Palmer, M. F., and Zerbe, L. E.: Control of Athetotic Tremors by Sound Stimuli, J. Speech Disorders **10**:303-319 (Dec.) 1945.

408. Wagley, P. F.: Study of Spasticity and Paralysis, Bull. Johns Hopkins Hosp. **77**:218-273 (Sept.) 1945.

409. Norfleet, G. M.: Cerebral Palsy and Reflex Action, Physiotherapy Rev. **25**:114-117 (May-June) 1945.

410. Norfleet, G. M.: Habits and Skills Among Cerebral Palsy Children, Physiotherapy Rev. **25**:155-159 (July-Aug.) 1945.

411. Jennings, D. C.: What Can Be Done for Spastic Child? Hygeia **23**:834 (Nov.) 1945.

412. O'Brien, V.: Treatment of Children with Cerebral Palsy, New York State J. Med. **45**:1548-1550 (July 15) 1945.

once or twice weekly. The types are classified as: (1) spasticity, (2) involuntary motions, mostly athetosis, and (3) incoordination or ataxia; treatment of each type is described. She discusses the complications such as mental retardation and hearing defects, and also discusses the causation.

Paralysis of Other Types.—Durman [413] discusses an operation for paralysis of the serratus anterior, recognizing that this is a rare condition. The operation described differs definitely from the Tubby operation and those described by Ober and Dickson.

Yaskin [414] deals with painful conditions of the upper extremities and shoulder girdle and discusses the differential diagnosis of neuritis, bursitis and coronary diseases in detail.

Muscle Disorders.—Simon and Senturia [415] present a report of a case of intermuscular lipoma of the thigh of definite traumatic origin.

Simon [416] reports 6 additional cases of muscle hernia in the arm and leg and the surgical treatment thereof, and in another paper Simon and Sacchet [417] review the literature and report 12 additional cases of muscle hernia in the leg.

Herz [418] discusses herniation of subfascial fat in relationship to pain in the lower part of the back, with a report of 85 cases.

Muscular Atrophy, Dystrophy and Syringomyelia.—Kay and Gaskill [419] describe an unusual heredofamilial neurologic disease which fits fairly well in the category of the Charcot-Marie-Tooth type of progressive muscular atrophy but with a strong hereditary picture involving many members of the family for several generations.

Donald [420] presents 3 cases of dystrophia myotonica in which the difficulty in relaxation is diminished by quinine and to some extent by epinephrine and calcium but which is increased by neostigmine; however,

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413. Durman, D. C.: Operation for Paralysis of Serratus Anterior, J. Bone & Joint Surg. **27**:380-382 (July) 1945.

414. Yaskin, J. C.: Painful Affections of Upper Extremity and Shoulder Girdle: Neurologic Considerations, Clinics **4**:275-293 (Aug.) 1945.

415. Simon, H. E., and Senturia, H. R.: Intermuscular Lipoma of the Thigh with Roentgenologic Findings, South. M. J. **39**:624-626 (Aug.) 1946.

416. Simon, H. E.: Muscle Hernia, with Report of Six Additional Cases in Arm and Leg, Mil. Surgeon **97**:369-374 (Nov.) 1945.

417. Simon, H. E., and Sacchet, H. A.: Muscle Hernias of the Leg, Am. J. Surg. **67**:87-97 (Jan.) 1945.

418. Herz, R.: Herniation of Subfascial Fat as a Cause of Low Back Pain: Results of Surgical Treatment in Thirty-One Cases, J. Internat. Coll. Surgeons **9**:339-346 (May-June) 1946.

419. Kay, C. F., and Gaskill, H. S.: Heredofamilial Neurologic Disease, Resembling Charcot-Marie-Tooth Type of Progressive Atrophy, in Chinese Family, Am. J. M. Sc. **210**:342-346 (Sept.) 1945.

420. Donald, R. A.: Dystrophia Myotonica, U. S. Nav. M. Bull. **45**:733-736 (Oct.) 1945.

quinine, while providing symptomatic relief, did not alter the course of the disease.

Evans and Love [421] discuss familial progressive dystrophy in three separate generations.

Pendergrass, Gammon and Powell [422] clearly show the changes in bone which may be associated with syringomyelia following severe trauma or minor injuries. They show the necessity for careful roentgen studies in such instances.

Traumatic Conditions of the Nerves.—Holmes, Highet and Seddon [396] discuss the ischemic nerve lesions occurring in Volkmann's contracture in a carefully worked up and extensive paper. They cover tests, causes, histologic observations and the present status of treatment.

Spiegel and Lewin [423] present 3 cases of tourniquet paralysis and discuss the various types of tourniquets and their effects.

Milch [424] discusses peroneal paralysis secondary to angulation of tibial fractures.

XIV. FRACTURES

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FRACTURES OF THE UPPER EXTREMITY

Fractures of the Humerus.—Godfrey [425] in a study of gunshot wounds of the humerus associated with fracture arrives at the following conclusions: 1. Gunshot wounds of the humerus present the problem of a fracture difficult to immobilize, plus a wound, often extensive, requiring management. 2. In order effectively to immobilize the frac-

421. Evans, W. A., and Love, C. H.: Familial Progressive Dystrophy in Three Generations Living in Same Neighborhood, Mississippi Doctor **23**:369-372 (July) 1945.

422. Pendergrass, E. P.; Gammon, G. D., and Powell, J. H.: Rapid Development of Bone Changes in Patient with Syringomyelia as Observed Roentgenologically, Radiology **45**:138-46 (Aug.) 1945.

423. Spiegel, L. J., and Lewin, P.: Tourniquet Paralysis: Analysis of Three Cases of Surgically Proved Peripheral Nerve Damage Following Use of Rubber Tourniquet, J. A. M. A. **129**:432-435 (Oct. 6) 1945.

424. Milch, H.: Anterior Transposition of Peroneal Nerve for Traction Paralysis, J. Bone & Joint Surg. **27**:608-614 (Oct.) 1945.

425. Godfrey, G.: Treatment of Compound Fractures of the Humerus, Australian & New Zealand J. Surg. **14**:114-118 (Oct.) 1944.

ture a shoulder spica cast must be used. [Ed. Note (L. D. B.): Because of the wide range of motion in the shoulder girdle a shoulder spica does not effectively immobilize the shoulder or upper fragment of a fractured humerus.] 3. Uninterrupted fixation combined with accessibility to the wound for the purpose of doing a proper dressing is essential. A prefabricated cast which is designed to accomplish these objectives is described.

The value of the hanging cast method of treatment for compound fractures of the humerus is discussed by Macey and Coventry.[426] In most instances the compound wounds were healed on removal of the casts. None of their patients showed extensive osteomyelitis. The technic of application of the cast is described.

[Ed. Note (L. D. B.).—Others have had the same satisfactory experience in the use of the hanging cast in treating compound fractures of the humerus.]

Fitts, Kirby and Brav [427] found that 3 per cent of all battle casualties during the North Burma campaign of 1943-1944 were complete gunshot fractures of the humerus. Sixty of 100 patients admitted for this lesion were followed long enough to determine the end result. In their hands débridement from one to several days after injury was of value in preventing or limiting infection and in shortening the period of wound healing. On the basis of their observations the authors arrived at the following conclusions: 1. Gunshot fractures of the humeral shaft can be adequately and comfortably evacuated in a hanging cast. 2. The hanging cast is highly satisfactory for treatment of these fractures in most instances. This method does not predispose to nonunion in cases with minor degree of bone loss. 3. Associated injuries to the nerves occur in a high percentage of these cases and are the most frequent cause of disability. 4. Ischemia due to constriction by the circular plaster is a constant danger. It can be prevented by adequate padding and splitting and spreading the plaster. 5. Secondary hemorrhage, no matter how minor, is an absolute indication for immediate exploration of the wound.

Raney [428] in a concise well illustrated paper reviews the indications and contraindications for the use of the hanging cast. The author concludes that when reduction is necessary it should be secured by other means before the hanging cast is applied. Demonstrable weakness of the soft tissues at the shoulder, post-traumatic or otherwise, contraindicates use of the hanging cast because of the danger of subluxation of the

426. Macey, H. B., and Coventry, M. B.: Use of Hanging Casts in Compound Fractures of the Humerus, U. S. Nav. M. Bull. **45**:33-36 (July) 1945.

427. Fitts, W. T.; Kirby, C. K., and Brav, F. A.: Gunshot Fractures of the Shaft of the Humerus, Surgery **18**:493-497 (Oct.) 1945.

428. Raney, R. B.: Treatment of Fractures of the Humerus with the Hanging Cast, North Carolina M. J. **6**:88-92 (Feb.) 1945.

shoulder joint. He also feels that in these fractures impaired mobility is more often due to changes in the soft tissues than to bony displacement and that the treatment with the hanging cast will often minimize stiffness of the shoulder.

Because he finds the current classifications of fracture of the head of the humerus, based on anatomic landmarks or relative position of the head and shaft of the humerus, unsatisfactory, Dehne,[429] after a study of 300 fractures of the humeral head and 37 fractures of the greater tuberosity, offers a new classification based on causation. In this classification there are three main groups: fractures caused by lateral, dorsal or central mechanism. With the lateral mechanism there is an inferior dislocation and a three fragment fracture. The dorsal mechanism produces an anterior dislocation and a two fragment fracture. With the central mechanism there is a head-splitting fracture. The roentgenologic appearance is discussed, together with the clinical properties of the three types.

Kelly and Riley [430] demonstrate by means of a model simulating a fracture through the lower third of the humerus the effect of the pull of the pronator muscle in producing varus deformity at the site of fracture. As long as the hand was pronated no deformity occurred, but when the hand was supinated lateral angulation of the distal fragment developed. They found the deformity in 16 of 24 unselected cases at the Ashford General Hospital.

Fractures About the Elbow.—Sandegard [431] reports his observations in 189 cases of fracture of the lower end of the humerus in children. Of these 118 were supracondylar, 34 lateral, 3 medial condylar, 3 transcondylar and 31 medial epicondylar fractures. Most of the patients had been treated surgically with fixation by means of Rissler's rust-proof nails, which were later removed. Although surgical treatment gave good results from a functional standpoint a large number of patients were found with cubitus varus or, in some instances, cubitus valgus deformities. For fractures of the medial and lateral condyles open reduction and replacement of the fragment is recommended. Removal of the fragment is generally not to be done. These cases all turned out well.

Boyer and Gale [432] present a general discussion of fractures of the elbow covering various types of fracture in this region and the treatment indicated for each. They point out that 80 per cent of the cases of

429. Dehne, E.: Fracture at Upper End of Humerus, S. Clin. North America **25**:28-47 (Feb.) 1945.

430. Kelly, R. P., and Riley, J. W.: Prevention of Angulation in Lower Third Humeral Fractures, Bull. U. S. Army M. Dept., January 1945, no. 84, pp. 100-101.

431. Sandegard, E.: Results of Treatment of Fractures of Lower End of Humerus in Children, Acta chir. Scandinav. **89**:1-16, 1943.

432. Boyer, D. W., and Gale, S. A.: Fracture of the Elbow, Rocky Mountain M. J. **42**:510-512 (July) 1945.

Volkmann's ischemic paralysis occur after supracondylar and dicondylar fractures and that delayed reduction increases the danger of this complication.

[Ed. Note (L. D. B.): This paper is an epitaph to "wait until the swelling goes down."]

"End results of fractures at the elbow are not good." With this sentence Stenstrom [433] introduces his study of 213 cases which came to his attention during a six month period at an Army reception center. Most injuries to the elbow in childhood are fractures, not sprains, and unless properly diagnosed and treated may lead to serious consequences. The author's conclusions are as follows: 1. Of 213 men with positive history of injury to the elbow, 97 had disabled and deformed elbow joints. 2. Better results can be obtained by exact diagnosis followed by proper treatment. Poor results will continue to follow missed diagnosis and improper treatment. 3. Limitation of joint movement due to capsular contraction or bone block is common after injuries to the elbow. 4. After union has occurred, elbow motion should be allowed to recover at its own rate. Forcing the joint is contraindicated. 5. Subsequent growth of the bone does not correct angulations and displacements. 6. Most fractures of the elbow can be reduced satisfactorily by closed manipulation, but some require operation at the start. 7. Anatomic reduction of all fractures of the elbow is imperative.

Allen and Gramse [434] report their results in 21 cases of supracondylar fracture of the humerus in children treated by the Dunlop traction method. The narrow oblique surface of the fracture makes retention of reduction difficult by any method other than traction. It is the rotation of the lower fragment which accounts for the alteration of the carrying angle and therefore the bad result. The traction is maintained for two to three weeks. The relatively long hospitalization is worth while to all economic groups because of the superior results obtained. In the 21 cases so treated, 8 had perfect result, 5 were not followed, 2 are too recent for classification and 2 have decreased carrying angles, 1 slight, 1 definite, but with good function in both. In the remaining 4 there was good function.

In discussing this same subject Fahey [435] presents an analysis of 100 consecutive fractures of the elbow in children, 60 of which were supracondylar. Insertion of a screw through the upper end of the ulna for the purpose of traction is recommended for certain displaced supracondylar fractures, where closed manipulation fails.

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433. Stenstrom, J. D.: Elbow Fractures, Canad. M. A. J. **52**:48-55 (Jan.) 1945.

434. Allen, P. D., and Gramse, A. E.: Transcondylar Fractures of the Humerus Treated by Dunlop Method, Am. J. Surg. **67**:217-227 (Feb.) 1945.

435. Fahey, J. J.: Fractures of the Elbow in Children, S. Clin North America **25**:59-80 (Feb.) 1945.

An excellent review of over 700 cases of fractures about the elbow in children 12 years of age or younger is presented by Boyd and Attenberg.[436] Damage to the nerves and blood vessels, which frequently accompanies these fractures, is often of greater consequence than the fracture itself. For this reason they caution the surgeon to ascertain the state of the nerve and blood supply to the arm before reduction and afterward. The authors give five types of fractures occurring about the elbow in children, and discuss each in a separate section.

Curry [437] gives a partial review of the literature on excision of the elbow and reports a case. The patient sustained a compound comminuted fracture of the elbow joint. At operation it was impossible to reduce the fracture and hold the fragments together. A complete excision was therefore decided on and carried out. The postoperative convalescence was uneventful, and the patient returned to light duty on the fortieth postoperative day. There was no pain; the elbow was flail and unstable but useful. Roentgenograms to show shape and range of motion are included in the article.

Fracture of the Head of the Radius.—Closed reduction of fractures of the neck of the radius in children is discussed by Goldenberg,[438] who recommends the manipulative technic described by Patterson in 1934. The author reports 4 cases, in all of which the head was reduced. In 1 case three attempts were made before reduction was accomplished. The fracture healed and excellent function resulted in 3 cases.

For comminuted fracture of the head of the radius without pronounced displacement Postlethwait [439] recommends aspiration of the hemarthrosis followed by injection of 5 to 8 cc. of 1 per cent procaine and active mobilization. The patient wears the arm in a sling and is instructed to exercise the arm within the limits of pain four times a day for twenty minutes each time during the first seven days. After this the sling is removed and the patient begins light tasks. Fourteen patients were treated in this manner and all made an excellent recovery except 1, who had a loss of about 5 per cent in carrying angle.

Fracture of the Forearm.—In an excellent résumé of fractures of both bones of the forearm Compere [440] reviews the anatomy of the forearm

436. Boyd, H. B., and Attenberg, A. R.: Fractures About the Elbow in Children, J. Tennessee M. A. **38**:243-251 (Aug.) 1945.

437. Curry, G. J.: Excision of the Elbow for Multiple Compound Comminuted Fractures, Am. J. Surg. **70**:243-248 (Nov.) 1945.

438. Goldenberg, R. R.: Closed Manipulation for the Reduction of Fractures of the Neck of the Radius in Children, J. Bone & Joint Surg. **27**:267-273 (April) 1945.

439. Postlethwait, R. W.: Modified Treatment for Fracture of Head of Radius, Am. J. Surg. **67**:77-80 (Jan.) 1945.

440. Compere, E. L.: The Treatment of Fractures of Both Bones of the Forearm, S. Clin. North America **25**:48-58 (Feb.) 1945.

and types of fractures and lists as essentials in treatment: (1) restoration of length; (2) accurate apposition of fracture surfaces; (3) correction of alinement; (4) wide separation between radius and ulna at site of fracture, and (5) complete immobilization with elbow at 90 degrees from metacarpophalangeal joints to well above the elbow, the forearm being completely supinated for fractures above pronator radii teres, or in midsupination; pronation for fractures distal to this insertion. Oblique fractures may be treated by continuous traction, some type of fixed skeletal traction or open reduction and plating. Old ununited fractures should be grafted. Recent compound ones need débridement and thorough cleansing (plating optional). Old infected fractures are treated by the Orr method.

[Ed. Note (L. D. B.): Plating of forearm fractures as in other fractures frequently leads to nonunion. In forearm fractures intermedullary wires as described by James Dickson give adequate immobilization and do not interfere with union.]

Fixation of fractures of the metacarpal and forearm bones by means of a Kirschner wire driven into the medullary canal is recommended by Long and Fett [441] as being consistent with principles of good treatment. The advantages are accurate reduction, absolute immobilization and early finger motion. The technic is described. In 12 patients treated by this method there was early development of callus. All healed in anatomic position, and none had stiffness of fingers.

Evans [442] discusses rotational deformity in fractures of both bones of the forearm and describes a method whereby the correct rotational position in which to immobilize the fracture may be determined.

Stuck [443] considers the treatment of fractures of the forearm from the anatomic and mechanical viewpoint. This is a good paper and should be read by all who are interested in the details of treatment as related to the cause of fractures.

Fracture at the Wrist.—An excellent article by White [444] on Colles' fracture is summed up as follows: 1. Do not attempt reduction without roentgenograms. 2. Do not attempt reduction without anesthetic, preferably general. 3. Do not stop short of anatomic reduction. 4. Do not use splints, if plaster is available. 5. Do not remove the cast too soon. 6. Remember to tell the patient to move his fingers. [Ed. Note (L. D. B.): And remember to move his shoulder.] 7. Do not

441. Long, R. D., and Fett, H. C.: Medullary Canal Wire Transfixion in Metacarpal and Forearm Fractures, U. S. Nav. M. Bull. **44**:253-256 (Feb.) 1945.

442. Evans, E. M.: Rotational Deformity in the Treatment of Fractures of Both Bones of the Forearm, J. Bone & Joint Surg. **27**:373-379 (July) 1945.

443. Stuck, W. G.: Anatomical and Mechanical Aspects of Treatment of Fractures of the Forearm, Texas State J. Med. **42**:232-240 (Sept.) 1945.

444. White, J. W.: Colles' Fracture, South. M. J. **38**:415-417 (June) 1945.

use too strenuous physical therapy actively or passively. 8. Do not resort to subsequent surgical treatment in older persons.

Attention is again called to delayed rupture of the extensor pollicis longus tendon following Colles' fracture. Coburn [445] reports such a case, in which the extensor carpi radialis longus tendon was transplanted into the distal end of the ruptured tendon with excellent results. His studies indicate that the lesion occurs on an average of once in every 250 cases, usually in women between 25 and 40 years of age. Cause of the rupture seems to be both trauma to the tendon and interference with its blood supply sustained at the time of fracture.

Ymaz [446] calls attention to the relative frequency of fractures of the carpal scaphoid in military services. Ninety-six of such fractures were treated between 1939 and 1943. Immobilization until the fracture is completely consolidated is emphasized.

Meekison [447] in a well written paper discusses fractures of the carpal scaphoid, fractures of the head of the radius and fractures of the medial malleolus. He considers fractures of the carpal scaphoid under two headings: fresh fractures (not a problem) and old fractures (a problem). Good results should be obtained in fresh fractures by closed methods in all cases. In old fractures there are four methods to consider: immobilization, excision, bone graft and arthrodesis of the wrist. Immobilization is used in fractures one to three months old which are accurately reduced. They should be kept up until union has occurred, or for four to six months. Excision is reserved for the fragment which shows evidence of aseptic necrosis. Bone graft was used by the author in 17 of his 115 cases. Arthrodesis gives a strong painless wrist. In discussing fractures of the head of the radius he emphasizes early operation and motion of the arm as soon as possible after surgical treatment.

Hambly [448] emphasizes that sprain of the wrist is clinically rarer than a fractured wrist and that therefore all sprained wrists should be examined roentgenologically. The scaphoid may be fractured at the proximal pole, the wrist or the tubercle. Aseptic necrosis occurs in about one third of all cases of fracture of the scaphoid through the proximal pole in spite of early treatment. Treatment of all three types

445. Coburn, D. E.: Delayed Rupture of the Extensor Pollicis Longus Tendon Following Colles' Fracture, Am. J. Surg. **68**:234-239 (May) 1945.

446. Ymaz, J. I.: Tratamiento de las fracturas del escafoides carpiano, Rev. san. mil., Buenos Aires **43**:1284-1289 (Sept.) 1944.

447. Meekison, D. M.: Some Remarks on Three Common Fractures: I. Fracture of the Carpal Scaphoid; II. Fractures of the Head of the Radius; III. Fractures of the Medial Malleolus, J. Bone & Joint Surg. **27**:80-84 (Jan.) 1945.

448. Hambly, E. H. T.: Fractures of the Carpal Scaphoid, M. Press **213**:260-263 (April 25) 1945.

of fresh fractures is by prolonged immobilization. In cases of established nonunion drilling or grafting of the fragments may be employed. The author prefers drilling.

A sharp warning against making a diagnosis of sprained wrist is also sounded by Soto-Hall.[449] This article is enhanced by photographs showing the reduction procedure and application of the plaster cast. The author discusses the different types of fracture and the methods of handling each one, stating that the methods suggested are not new but have stood the test of time. He believes that in 95 per cent of the cases healing will occur within four to five months, and if it does not prolonged immobilization is not recommended, because there are complications present which should be treated surgically. When fracture of the scaphoid is associated with luxation of the semilunar (this occurs in about 12 per cent of the cases) the wrist should be held in slight volar flexion for the first four weeks. Otherwise there may be a redislocation of the semilunar bone.

Kaplan[450] calls attention to the common observation that when traction is applied to the entire finger for treatment of a fracture of the corresponding metacarpal, stiffness will develop regardless of the type of traction. He recommmends reduction of the fracture with the patient under local anesthetic and traction applied through the proximal phalanx of the fractured metacarpal by means of a traction wire drilled through the bone and the use of a Granberry finger bow. The entire procedure is well described and illustrated.

[Ed. Note (L. D. B.): Infection about the site of wire traction in a finger may lead to serious disability.]

Barba Inclán A.[451] reports 4 cases of metacarpal fractures in which treatment was by the method of Eugene F. Berkman of the United States Army. The fracture is reduced with the patient under local anesthesia, after which a heavy Kirschner wire is introduced through the fractured bone and the adjacent metacarpals in such a way as to fix the fracture. For oblique or spiral fractures two or more wires are used. No postoperative cast or splinting is necessary. Function of the hand is preserved and the convalescent period is shortened. This method is not suited to fractures of the first metacarpal.

[Ed. Note (L. D. B.): The complications from such therapy may lead to more serious disability than would less accurate reduction and fixation.]

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449. Soto-Hall, R.: Recent Fractures of the Carpal Scaphoid, J. A. M. A. **129**:335-338 (Sept. 29) 1945.

450. Kaplan, E. B.: Treatment of Fractures of Metacarpals and Proximal Phalanx by Skeletal Traction, Bull. Hosp. Joint Dis. **5**:99-109 (Oct.) 1944.

451. Barba Inclán: Tratamiento de las fracturas de los cuatro últimos metacarpianos, por fijación interna, Cir. ortop. y traumatol., Habana **12**:72-76 (April-June) 1945.

Vasko [452] describes a simple method for reducing fractures of the neck of the metacarpals by flexing the metacarpophalangeal joints to a right angle and forcibly pushing back on the proximal phalanx against the metacarpal head, counterpressure on the metacarpal being maintained. When the fracture is reduced the finger and the hand are splinted in this position by adhesive strapping. The author reports a series of about 88 cases in which this treatment was used with good results. Fixation is maintained for three to four weeks. In 3 cases displacement recurred. Two patients removed the tape, but reduction was successfully accomplished a second time. In the third case the patient did not return until union was present, and some deformity was the result.

[ED. NOTE: One of the reviewers (L. D. B.) has found a similar method, plaster being used in place of adhesive tape, most satisfactory. The finger must be observed for pressure symptoms over the proximal interphalangeal joint.]

Hipps [453] reports a case of dislocation of the base of the fifth metacarpal and states that a study of the literature reveals that only 9 cases have been previously reported. Signs include the tendency for the fifth finger to spread away from the fourth, shortening of the fifth finger and tenderness around the base of the fifth metacarpal. Roentgenograms reveal the dislocation.

Reduction was easy but difficult to maintain. It was accomplished, however, by means of two nonpadded plaster splints applied in such a way as to maintain constant pressure over the base of the fifth metacarpal. Fixation was maintained for six weeks, and the final result was excellent. The author discusses the types of dislocation previously reported and gives an analysis of the literature.

An almost identical case is presented by Clement,[454] except that in this instance reduction could not be maintained. Plaster of paris was thought to be inadequate, and a Kirschner wire was inserted in the proximal third of the metacarpals to the little, ring and middle fingers. Following this, fixation was stable and the normal appearance of the hand was restored. The patient made an uneventful recovery.

Miscellaneous.—For fixation of small, fragile bone fragments in fractures in which exact position of the fracture is essential Herzog [455] has devised a special method. A spiral Kirschner wire (1.5 mm. in diameter) is drilled through the fragments and diagonally through the

452. Vasko, J. R.: Metacarpal Neck Fractures, Mil. Surgeon **97**:121-122 (Aug.) 1945.

453. Hipps, H. E.: Simple Isolated Dislocation of the Fifth Metacarpo-Hamate Articulation, U. S. Nav. M. Bull. **45**:945-950 (Nov.) 1945.

454. Clement, B. L.: Fracture-Dislocation of the Base of the Fifth Metacarpal: A Case Report, J. Bone & Joint Surg. **27**:498-499 (July) 1945.

455. Herzog, K.: Methode zur Osteosynthese kleiner brüchiger Knochenstücke, Chirurg **15**:669-672 (Nov. 15) 1943.

bone from which they have been separated in the process of fracture. The wire is left in place and the operation completed by securing the ends of the wire. It is left in position until healing is complete and then removed through two small incisions. The author illustrates his procedure with drawings and roentgenograms.

Bate [456] describes an operation to prevent locking of the proximal interphalangeal joint of the fifth finger in hyperextension. The procedure consists of suturing the torn volar ligament and repairing the lateral capsule in such a way as to shorten the volar surface by suturing the capsule more proximally. An excellent result was obtained in an aviator who was unable to operate the throttle control on a four motor plane because of locking of the fifth finger in hyperextension.

Cutting [457] in discussing injuries of the hand in working men stresses the importance of respecting all injuries, even small and apparently insignificant ones. They should receive meticulous and intelligent care. In his conclusions the author emphasizes the following points: (1) early definitive care of fractures of the hand, since they must be considered surgical emergencies; (2) accurate reduction, and traction when necessary, and (3) the use of nonpadded, well molded plaster splints which provide maximum immobilization of the fragments, and yet allow maximum function and use of the noninjured portion of the hand.

Murray [458] recommends wires placed longitudinally in the medullary canal of the clavicle, the radius and the ulna, and in some cases of the humerus and the long bones of the hands and the feet, as providing a method of treatment which gives improved results in these fractures. In many cases the wires can be introduced after closed reduction, otherwise a small incision is made.

A series of 154 cases representing various types of fractures is reported. In these cases there was no evidence that Kirschner wires of small or medium size traversing the articular cartilage harm the joint. There was no migration of wires placed in bones even though they cross joints. In only 1 case was there infection.

FRACTURES OF THE LOWER EXTREMITY

Fractures About the Hip Joint.—Ellis [459] reports 44 cases of war wounds in the region of the hip joint, expressing his dissatisfaction with

456. Bate, J. T.: An Operation for the Correction of Locking of the Proximal Interphalangeal Joint of Finger in Hyperextension, J. Bone & Joint Surg. **27:** 142-144 (Jan.) 1945.

457. Cutting, C. C.: Hand Fractures in Industry, California & West. Med. **62:**21-22 (Jan.) 1945.

458. Murray, G.: Use of Longitudinal Wires in Bones in the Treatment of Fractures and Dislocations, Am. J. Surg. **67:**156-164 (Feb.) 1945.

459. Ellis, J. S.: Wounds in Region of Hip-Joint, Lancet **2:**490-492 (Oct. 20) 1945.

the results on the whole. He discusses in some detail treatment, including various types of splintage with comparison of different methods, and suggestions for improvement. The results are closely analyzed as to causes for unsatisfactory results, which included shortening, slow healing, chronic infection and prolonged mobility, with an earnest effort to devise methods for improved results. After this careful analysis, he presents recommendations here epitomized: (1) early treatment of the wound with moderate débridement and removal of foreign material; (2) delayed primary or secondary closure; (3) early decision as to desirability of ankylosis, with (*a*) application of a spica to the hip if it is to be ankylosed or (*b*) traction if motion is to be preserved, and (4) prompt definition of complications such as foreign body, sequestrum and abscess cavity, with early, adequate and, if necessary, radical surgical treatment.

Sonnenschein [460] describes a series of cases of what he calls "dashboard acetabular injuries," caused by the current practice of riding in a car with the hips flexed and the knees against the instrument panel. In this position, the thrust of the car against the knee transmits the power through the femoral head against the shallow posterior rim of the acetabulum. Thus the hip is dislocated, the acetabulum fractured, or both, depending on the degree of violence plus the angle of impingement. He discusses two common complications: first, injury to the sciatic nerve, which must be treated appropriately, and, second, aseptic necrosis of the head and the neck of the femur. To prevent the latter, early reduction of dislocation of the head plus three weeks of protection in bed is suggested, with further protection as indicated.

[Ed. Note (L. D. B.): If the circulation to the head and the neck of the femur has been disturbed it is difficult to determine the length of time that weight bearing should be avoided and traction should be continued in the treatment of dislocation of the hip. Frequently roentgenograms will not show signs of aseptic necrosis under a year or more. It is hoped that the Surgeon General's Office will prepare a report on the results obtained in the treatment of a large series under controlled conditions and if possible an opinion as to the effect of early weight bearing.]

MacAusland and Lee [461] discuss fractures of the acetabulum, particularly (1) fractures of the superior-posterior rim and (2) central fractures. Three cases are presented with internal fixation of the fragment of the hip. Late result after two years of apparent success was necrosis of the femoral head, plus later destruction of the hip joint. The

460. Sonnenschein, H. D.: Dashboard Acetabular Injuries, Bull. Hosp. Joint Dis. **5**:60-70 (Oct.) 1944.

461. MacAusland, W. R., and Lee, H. G.: Fractures of the Acetabulum, Am. J. Surg. **69**:213-220 (Aug.) 1945.

authors believe that the surgical treatment of fractures of the acetabular rim is advisable to shorten convalescence and hasten healing. One case is presented in detail of central fracture with general discussion of treatment, including various methods of obtaining lateral pull by screw, pin and bolt. In these cases long follow-up will frequently show disappointing results with destruction of the hip joint.

Haas [462] describes a case of fracture dislocation of the hip with a portion of the head remaining in the acetabulum. He discusses the difficulties of treatment with inevitable disability. In his case treatment was by excision of fragment and reposition of remaining head. Later there were excision of the fragment of the head, which had fractured subsequent to reduction, reconstruction and fusion, all of which failed. He leans toward early reconstruction if simple excision of the fragment fails.

A case is reported by Abbate [463] of an old fracture of the ischial tuberosity by avulsion. This had been undetected and was untreated with poor result early but with improved condition following conservative treatment later. He advises surgical intervention only for persistent disability.

An ambulant cast with caliper attachment and hinged knee brace is described by Phalen [464] for use in those cases in which it is desirable to protect the hip with a cast but still permit motion at the knee and the ankle to prevent stiffness. The apparatus consists of a short spica (plaster) with embedded metal bars to receive bars for a brace with drop ring knee and caliper heel. He urges its use to prevent prolonged immobilization of the knee in chronic conditions resulting from compound injuries about the hip.

Intertrochanteric Fractures.—Posch and Abbott [465] refer briefly to recent excellent summaries on various types of treatment for intertrochanteric fractures, including (1) external splints, (2) traction devices and (3) internal fixation. These authors conclude that internal fixation is the method of choice if available. However, in many instances—namely, poor surgical risk or severe coma—internal fixation may not be feasible. They report 14 cases of this type, in which treatment was carried out by use of the hanging cast. The patients were from 48 to 91

462. Haas, S. L.: Longitudinal Fractures of Head of Femur Associated with Dislocation of Femur, Am. J. Surg. **69**:402-405 (Sept.) 1945.

463. Abbate, C. C.: Avulsion Fracture of the Ischial Tuberosity: A Case Report, J. Bone & Joint Surg. **27**:716-717 (Oct.) 1945.

464. Phalen, G. S.: A Cast-Caliper Brace for Immobilization of the Hip, J. Bone & Joint Surg. **27**:724-726 (Oct.) 1945.

465. Posch, J. L., and Abbott, W. E.: Treatment of Intertrochanteric Fractures of the Femur: Use of the Hanging Cast, Am. J. Surg. **70**:369-373 (Dec.) 1945.

years old. As described by Johnson, the method can be carried out with the patient under local anesthetic and is a simple procedure. A detailed description of the method is given; mortality was 2 per cent, with results comparing favorably with all other methods except internal fixation. Since these cases were selected because internal fixation seemed inadvisable, the authors conclude that the method has merit.

[ED. NOTE: This method of treatment would seem to be well adapted to another group of cases, namely, those in which a skilled surgical team with adequate operating facilities was unavailable.]

Cohn and Vonburg [466] state that "treatment of intertrochanteric fractures of the femur has lagged behind the development of internal fixation for fractures of the femoral neck. It is generally assumed that fractures in the region of the trochchanters will heal regardless of position and method of treatment. This false assumption is based on the rich blood supply of the extracapsular area as compared with the poor vascularization of the intracapsular or femoral neck region. Although healing takes place in a higher percentage of intertrochanter cases than in neck fractures, nonunion does occur, as the authors have observed. Much more important than the occasional case of non-union is mal-union, the percentage of the latter being surprisingly high." The authors describe in detail the technic for insertion of a blade plate, which they feel is superior to other types of devices for internal fixation. Careful selection of cases must be made to avoid disappointing complications.

Fractures of the Neck of Femur.—Many good articles were published on this subject in 1945, but no radical changes or startling ideas have been presented. Rather have there been suggested refinements of technic or reports of isolated unusual cases. Duhamel [467] reports success with the use of a roentgenographic guide consisting of a bent (90 degree) metal plate as described by Huet and Huguier. Godoy-Moreira [468] adds 80 patients to the series reported in 1940; he used his special stud bolt screw and made considerable simplification of technic and instruments. He reemphasizes that the good results obtained are due to the firm impaction secured by the stud bolt screw. However, he suggests the use of a short spica cast for a few weeks subsequent to the first three weeks after the operation. [ED. NOTE: Altogether this seems to be an extremely efficient method for internal fixation in the hands of one familiar with its use.]

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466. Cohn, B. N. E., and Vonburg, V. R.: The Surgical Treatment of Intertrochanteric Fractures, Rocky Mountain M. J. **42**:587-592 (Aug.) 1945.

467. Duhamel, B.: Indications vitales et technique de l'enclouage du col fémoral, Presse méd. **53**:267-268 (May 26) 1945.

468. Godoy-Moreira, F. E.: Difficult Fractures of the Neck of the Femur Treated with Stud-Bolt Screw, J. Bone & Joint Surg. **27**:595-602 (Oct.) 1945.

Gervis [469] suggests the use of a modified Smith-Peterson nail to prevent the complication of extrusion of the nails. He comments on the fact that fixation of the head of the nail into the femoral cortex is not advisable since it may lead to distraction of the fragments or impingement of the nail into the acetabulum. He aims at securing fixation at the point of the nail and provides this by notching each flange about ¼ inch (0.64 cm.) from the point. It was hoped that these notches would serve to fix the point of the pin in the femoral head. The method has been tried successfully in 24 cases. The author comments that after union has occurred, there is no difficulty in withdrawing the pins.

Rowe [470] describes a new type of guide wire for insertion of internal fixation into the femoral neck.

[ED. NOTE: This pin seems to have considerable merit, and for the technical details of construction of pin and its use one should carefully study the original article.]

Heyman [471] reports a case of bilateral fractures of the femoral neck occurring fourteen and seventeen months respectively after extensive irradiation for a carcinoma of the cervix. In neither hip was there direct trauma. Neither showed signs of metastasis. Each was pinned promptly with a Smith-Peterson nail, and both responded promptly and well to internal fixation and two years later were still well healed with no evidence of necrosis. Heyman attributes the good results to prompt and efficient internal fixation.

Virgin and MacAusland [472] discuss in detail a "continuous traction screw" for fractured femoral neck (for details the article should be consulted). They report follow-up on 17 cases with 76.8 per cent of bony union. They emphasize particularly the importance of maintenance of firm apposition by the spring traction inherent in the screw.

Leadbetter [473] reviews carefully the whole history of the fractured hip, pointing out the tremendous advance due to internal fixation. He advises great attention to the patient's general condition and says that this is as important as is good operative technic. This whole

469. Gervis, W. R.: A Modified Smith-Peterson Nail for Fractures of the Neck of the Femur, Proc. Roy. Soc. Med. **38**:615-616 (Sept.) 1945.

470. Rowe, M. L.: A Simple Guide Pin for the Insertion of Devices of Internal Fixation into the Femoral Neck, J. Bone & Joint Surg. **27**:522-523 (July) 1945.

471. Heyman, C. H.: Spontaneous Bilateral Fracture of the Neck of the Femur Following Irradiation, J. Bone & Joint Surg. **27**:674-678 (Oct.) 1945.

472. Virgin, H., Jr., and MacAusland, W. R.: A Continuous Traction Screw for Fixation of Fractures of the Hip: Review of Twenty-Three Cases, Ann. Surg. **122**:59-67 (July) 1945.

473. Leadbetter, G. W.: The Problem of the Fractured Hip, Nebraska, M. J. **30**:309-313 (Sept.) 1945.

problem of the patient must be considered rather than just the reduction and fixation.

Golodner, Morse and Angrist[474] report in detail 304 cases of fractures of the hip with 86 deaths (28 per cent). Two thirds of the deaths were in patients between 70 and 80 years of age. Necropsy in 25 cases revealed pulmonary embolism in 9 and bronchopneumonia in 8. Thus, 68 per cent showed definite pulmonary cause of death, which in 53 per cent of these was due to embolism. They conclude: "1. Pulmonary embolism from venous thrombosis in the vessels of the lower extremities is the most frequent cause of death in cases of fracture of the hip. 2. Venous thrombosis and embolism are less frequent in patients who are made ambulant early. 3. Prophylactic bilateral superficial femoral vein ligation combined with lumbar sympathetic block is suggested as most ideal for the prevention of pulmonary embolism in fractures of the hip, especially in those who cannot be made ambulant at an early date.

Henderson and Hinchey[475] report on the Colonna reconstruction operation and discuss the details of the technic including after-care, both immediate and late. Some modification of technic was suggested. Out of 22 cases with complete follow-up results were excellent in 31 per cent, good in 23 per cent, fair in 23 per cent and poor in 23 per cent. The operation is recommended for selected cases.

Fractures of the Shaft of the Femur.—That the problem of the fractured femoral shaft is still not satisfactorily solved is attested by the usual large series of articles covering this subject. No fewer than thirty articles on fractures of the femur were reviewed, and over half of these concerned fractures of the shaft. To reveal the continuing trend away from external skeletal fixation (Stader and Haynes type), no one of these authors mentioned this except to condemn it. McKeever[476] reports 47 cases in which treatment had previously been given elsewhere: one half by traction, two sixths by internal fixation and one sixth by external skeletal fixation. A careful analysis in regard to time of recumbency, time of protection, roentgenologic evidence of union, degree of shortening, degree of atrophy and other complications is made. He concludes that, in the average hospital by the average surgeon, traction is the best method. Many authors discuss various methods for obtaining traction. James[477] reports a general

474. Golodner, H.; Morse, L. J., and Angrist, A.: Pulmonary Embolism in Fractures of the Hip, Surgery **18**:418-423 (Oct.) 1945.

475. Henderson, M. S., and Hinchey, J. J.: The Colonna Reconstruction Operation for Ununited Fractures of the Neck of the Femur, Minnesota Med. **28**:641-644 (Aug.) 1945.

476. McKeever, F. M.: Femur Fractures: Fracture of Shaft in Adults; Evaluation of Methods of Treatment, J. A. M. A. **128**:1006-1012 (Aug. 4) 1945.

477. James, E. S.: Treatment of Fractures of the Shaft of the Femur, Manitoba M. Rev. **25**:48-49 (Feb.) 1945.

review of various types of traction used in various age groups and locations. Von Susani [478] discusses at some length the various methods of traction and discusses a method of intrinsic traction within a splint (much like the Siebrandt frame) which obviates the necessity for fixation of the apparatus, and hence the patient, to the bed. Traction is obtained by suitable springs and weights within the suspension splint itself. Modlin,[479] in discussing fractures of the lower part of the femur, recommends double traction with a Kirschner wire through the upper part of the tibia for linear traction plus a second Kirschner wire through the lower femoral fragment to control rotation of this fragment. Deacon [480] describes in detail four fractures of the lower part of the femur, three of them including separation across part of the lower epiphyseal plate with split up the shaft. Results were only fair with conservative measures such as traction, manipulation and cast. [ED. NOTE: The disturbance in growth noted in these cases may often be prevented by prompt, accurate replacement, surgical if necessary, of the dislocated epiphysis.] Fisk [481] favors the use of a suspension traction splint similar to the Tobin splint, with weight so arranged as to permit constant exercise to prevent stiffness of the knee in fractures of the shaft and reports 33 cases in which it was used successfully. Tavernier [482] describes in detail an operation to release the stiff knee should stiffness occur. He reasons that the restriction of motion is due to adhesions in the suprapatellar pouch and between the patellar edges and the femur. The plastic operation is designed to release the patella on both sides, split the patellar tendon, free the pouch laterally and flex the knee. It seems a formidable procedure but in the author's hands was rather successful. [ED. NOTE: One wonders whether patellectomy would not simplify the procedure and hasten convalescence.] Van Domselaar [483] recommends the manipulation method popularized years ago by the late Willis Campbell. He advocates reduction of the fracture of the shaft with application

478. von Susani, O.: Ueber die Dauerzugbehandlung von Ober- und Unterschenkelbrüchen mit besonderer Berücksichtigung der Schussverletzungen, Deutsche Ztschr. f. Chir. **258**:363, 1945.

479. Modlin, J.: Double Skeletal Traction in Battle Fractures of Lower Femur, Bull. U. S. Army M. Dept. **4**:119-120 (July) 1945.

480. Deacon, A. E.: Fractures of the Lower Third of the Femur, Manitoba M. Rev. **25**:45-48 (Feb.) 1945.

481. Fisk, G. R.: La fractura de la diáfisis femoral: Nueva aportación al problema, Prensa méd. argent. **31**:2433-2437 (Nov. 29) 1944.

482. Tavernier, L.: Technique de la cure opératoire des raideurs incoercibles du genou après les fractures du fémur traitées par traction sur broche de Kirschner, Lyon chir. **40**:9-14 (Jan.-Feb.) 1945.

483. van Domselaar, F.: Fractura de diafisis femoral: Tratamiento por yeso, Rev. méd. d. Hosp. brit. **1**:15-20 (Oct.) 1944.

of a long single or short double hip spica. Westerborn [484] reports 28 cases in which Kuntscher's method of intramedullary nailing was used. Half were recent fractures, and half pseudarthrosis. The method may be used for any type of fracture, but in most cases he advises open visualization of the fracture rather than closed manipulation. Especially in pseudarthrosis it is necessary to freshen up the fracture line and obtain revascularization to promote healing. The author discusses various advantages of the method and seems well convinced of its efficacy. A second grouping of cases of fracture of the femur concerns compound fractures, particularly war injuries. Collom and Ewing [485] in a complete and careful study report 100 cases divided into four groups.

Group I. Twenty battle fractures treated without wound closure or penicillin therapy by skeletal traction. Group II. (*a*) Nine battle fractures treated the same as group I that became septic and were then treated by surgery and penicillin therapy. Five had delayed internal fixation with bone plates. (*b*) Forty-one battle fractures treated by wound closure with drainage and penicillin therapy. Eleven were treated by bone plate fixation, the remainder by skeletal traction. Group III. Twelve battle fractures treated by wound closure (without drainage in 11). Delayed internal fixation by plating was done in 3 cases, 9 being treated by skeletal traction. Group IV. Eighteen simple fractures treated by skeletal traction. Four required delayed open reduction and plating . . . From the standpoint of wound healing and fracture alignment, definitive surgery, consisting of secondary closure of wounds with drainage and skeletal traction, has been most satisfactorily instituted in the period from five to ten days after injury. In the cases of Group I, where surgical closure of wounds was not performed, infection developed by secondary invasion even in those which were previously non-suppurative. These injuries required wound revision and excision of devitalized tissue. Tissue closure was best attained by deeply placed interrupted vertical mattress sutures of silk in the skin. Proper dependent drainage should be a routine procedure. Internal fixation with vitallium plate and screws was done in twenty-four cases. Twenty of these were done in compound fractures and four in simple fractures. Open reduction of compound fractures can be safely performed under penicillin protection even in the presence of infection as was done in five cases in Group II *a*. Twenty-three of the cases on which internal fixation was done obtained good results. In the other case there was loosening of the screws because of poor technique requiring removal of the plate, osteotomy and application of a second plate. The ultimate result in this case was satisfactory.

The indications for internal fixation in this group of cases, are given. Although open reduction with internal fixation was performed in 24 per cent of the compound fractures, excellent alinement was obtained by traction in the most severely comminuted fractures.

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484. Westerborn, A.: Nailing in Marrow Cavity in Cases of Recent Fracture and Pseudarthrosis: Report of Twenty-Eight Cases. Acta chir. Scandinav. **90**: 89-104, 1944.

485. Collom, S. A., Jr., and Ewing, W. M.: A Comparative Study of One Hundred Fractures of the Shaft of the Femur, Ann. Surg. **122**:773-792 (Nov.) 1945; M. Bull. Mediterranean Theat. Op. **3**:37-39 (Feb.) 1945.

Wound healing in twenty-nine cases treated by the open method (Groups I and II *a*) was unsatisfactory with exudation for over two months in twenty-six of the patients. In the other fifty-three soldiers with compound femoral fractures wound healing by primary intention resulted in two thirds of the cases and all wounds were healed in an average time of four weeks. The other one third of the cases in this group healed by secondary intention without systemic complications. In the nine cases of sepsis treated with delayed penicillin therapy temperature elevation persisted for fifty-six days after admission. . . . In the presence of abscess formation or necrotic tissue penicillin was not a curative agent nor does it prevent systemic signs of infection. . . . Although infection in the wound did not materially affect the appearance of callus on roentgenologic examination, delayed union of bone was in direct proportion to the length of time drainage persisted. As far as can be demonstrated from the groups of cases, bone healing was not accelerated by the use of penicillin except in its role of controlling invasive infection. [There were] no deaths or amputations in this hospital among patients with femoral shaft fractures.

[ED. NOTE: This study is a thoroughly analyzed and carefully reported series, reported without prejudice, and well merits consultation of the original article.]

Burns and Young [486] report 70 cases of compound fracture in which treatment was with penicillin: in 48 of these the wounds were closed secondarily within three to ten days and without drainage. The rate of healing and restoration of function in these cases equaled that of closed fractures. The authors decry the use of drainage in these cases as prolonging healing and encouraging suppuration. The patients had good primary care and reached the authors in good condition and were operated on promptly. There were no deaths or amputations and there was no general sepsis after operation. McEwen, Bickerton and Pilcher [487] report 64 cases completely in accordance with the foregoing. Better results were obtained when wounds were sutured than when they were left open; best results were obtained when wounds were closed between the sixth and the tenth day after wounding. The rate of healing improved when a ten day course of penicillin was substituted for a five day course (average of twenty-seven days against forty-three). Intramuscular administration of sodium penicillin did not retard the rate of union of fractures, and the presence of metallic foreign bodies did not affect materially the prospects of healing. So good was the work of the forward surgeons in the central Mediterranean command that most wounds complicated by major fractures reached the center clean enough for prompt closure without reopening or drainage.

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486. Burns, B. H., and Young, R. H.: Compound Fractured Femur, Treated with Aid of Penicillin, Lancet **1**:236-238 (Feb. 24) 1945.

487. McEwen, R. J. B.; Bickerton, J. G., and Pilcher, M. F.: Compound Fractures of Femur: Two-Stage Operation, Lancet **1**:623-624 (May 19) 1945.

Fractures of the Patella.—The increasing popularity of patellectomy as the treatment for fractures of the patella is attested by reports from two authors.

Schmier [488] discusses in detail many methods for treatment of fractures of the patella and notes that the many complications arising from the various other methods have brought patellectomy into favor. A careful description of operative technic is given, plus great attention to after-care. He emphasizes the improved end results from patellectomy with normally functioning knee, complete stability and powerful extension. The patient can walk long distances and freely climb stairs. Difficulty in kneeling soon disappears. In 1 case there was a postoperative infection, but even in this case a good result was obtained. He concludes in part as follows:

> 2. When one considers the possibility of fibrous union or nonunion, union with restricted mobility and instability, and union with secondary arthritic changes, one notes the shortcomings of open as well as closed reduction of the patella. 3. The high incidence of refracture of the patella, even after open reduction, reveals the need for a more effective method of treatment. 4. Excision of the patella, either partial or complete, is the method of choice in fractures. 5. Partial excision with removal of the small comminuted fragments alone is indicated only when a large uninvolved portion of the patella can be left *in situ*. 6. In all other instances of fracture, total excision is preferable for the following reasons: (a) Rapid progressive uneventful recovery usually ensues; (b) postoperative immobilization and convalescence are shortened; (c) strong, stable, and freely movable knee joints are generally obtained; (d) even when complicating infections occur, the prognosis is better when patellectomy has been performed; (e) excision of the patella does not impair the efficiency of the knee. 7. Regeneration in kind may occur following excision of the patella to protect the exposed femoral condyles.

Sanchís Olmos [489] comments on the increasing popularity of patellectomy in England and the United States and approves of the procedure, reporting 1 case in detail. The discussion of patellectomy for the fractured patella is pointed up by a unique account from Moberg,[490] who reports a twenty year follow-up obtained from the National Insurance Office files on 44 cases of fracture of patella treated operatively in Sweden. The results were not good. The average hospital stay was fifty-three days. Total disability lasted one hundred and thirty-three days. One hundred and sixty-four days passed before the patient returned to full time work or received a settlement. Forty-one per cent had permanent disability, averaging 21 per cent, with various complications including secondary rupture of sutures, pseudarthrosis,

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488. Schmier, A. A.: Excision of the Fractured Patella, Surg., Gynec. & Obst. **81**:370-378 (Oct.) 1945.

489. Sanchís Olmos, V.: Patelectomía por fractura de la rótula, Cir. d. ap. locom. **2**:84-88 (Jan.) 1945.

490. Moberg, E.: Operative Therapy and Prognosis in Fractures of Patella, Acta chir. Scandinav. **90**:295-316, 1944.

extensor defect, angulation of fragments and arthritis. He comments that although these are old cases he doubts whether recent cases are much better, since methods have not changed except for refinements of technic. [ED. NOTE: This is a thought-provoking report. Perhaps patellectomy, partial or complete, is the answer.]

Fractures of Shaft of the Tibia and Fibula.—Lathrop [491] reviews in some detail the anatomy of the lower part of the leg and the physiology of bone healing. As the title indicates, he emphasizes the importance of complete, accurate immobilization, plus continuous and firm fixation. He reviews the various salient features of the individual fracture with suggestions as to their care. A detailed discussion of the place and relative merits of casts, traction and internal fixation is given, together with a plea for better care.

Gervis [492] recommends internal fixation for oblique fractures of the lower third of the tibia and especially advocates use of one long screw across the obliquity.

[ED. NOTE: It would seem that if the fracture is exposed surgically, more adequate fixation than one screw could be readily used.]

Pease [493] has used the beaded Kirschner wire, developed by Thomson and Ferciot (*Surg., Gynec. & Obst.* **64:** 831, 1937) in 68 cases of fracture of the leg, with no instance of nonunion or infection. He considers it a procedure which should be in the armamentarium of all those who treat fractures. It has its limitations, but likewise its advantages. It requires no expensive equipment. Reductions can be attained without trained assistants. It diminishes the number of open reductions of legs, thereby avoiding vascular interference and possible infection. No foreign material is left in the bone. The patient may be ambulatory as soon as recovery from the anesthetic is accomplished. Not only good anatomic but also good functional result is obtained. Oblique and spiral fractures, "bumper" fractures, tibiofibular dislocations and open reduction of tibial plateau fractures are ones best suited for its application.

Funsten and Lee [494] in a scholarly article discuss 149 consecutive cases of fracture of the tibia and fibula and femur. The original article should be read, but the following conclusions are understandable:

1. The long bones of the lower extremity are the biggest and strongest bones in the body. The force required to break them must necessarily be great, and

491. Lathrop, M. R.: The Importance of Accurate Reduction and Adequate Immobilization of Fractures of the Lower Leg, Nebraska M. J. **30**:120-124 (April) 1945.

492. Gervis, W. H.: A One Screw Technique in Oblique Fractures of the Tibia, Proc. Roy. Soc. Med. **38**:616 (Sept.) 1945.

493. Pease, C. N.: Beaded Wires in Treatment of Fractures of the Legs, S. Clin. North America **25**:174-191 (Feb.) 1945.

494. Funsten, R. V., and Lee, R. W.: Healing Time in Fractures of the Shafts of the Tibia and Femur, J. Bone & Joint Surg. **27**:395-400 (July) 1945.

the damage taking place at the time of injury is not only in the bone, but in the surrounding tissues. The speed of healing of fractures is usually in proportion to the amount of available circulation to and between the fragments. 2. In spite of the foregoing deduction, all the causes of delayed union and of non-union have not yet been determined. 3. The percentage of delayed union and non-union in fractures of the femur is not so great as in fractures of the tibia. 4. There are more cases of delayed union and non-union in the middle third of the tibia than in the upper and lower thirds. 5. The majority of [the author's] patients received some form of calcium therapy during their fracture treatment, with little recognizable effect on the end result. 6. In the instructions to patients and students, due consideration should be given to the slowness and uncertainty of the healing of fractures of the tibia and femur, so that patients may be prepared for the long period of time possibly necessary for the healing of these fractures. 7. The use of skeletal traction and the use of internal or external skeletal fixation in no way speeds the healing time of bone, and in some instances retards it, because of distraction, infection, or the osteolytic effect of the metals used. 8. In the series of cases . . . presented, circumstances in some instances necessitated the use of skeletal traction, plating, and external fixation (Haynes). In none did [the authors] feel that the results obtained by such methods were in any way superior to those of conservative treatment, when alignment could be maintained even at the expense of a loss of length of as much as three-quarters of an inch.

Malleolar Fractures.—The increased interest in malleolar fractures and particularly in the advisability of internal fixation is shown by several articles on this subject. Muller [495] ably describes the fracture of the internal malleolus which goes on to fibrous union or nonunion because of interposition of fibrous tissue between the fragment and the fracture bed as a result of incomplete or insecure reduction. He advises open reduction with fixation by a long vitallium or wood screw. This minimizes chance of fibrous union, maintains reduction and permits early active motion. This author advises motion as early as the second day.

[ED. NOTE: The method described is excellent and deserves more general acceptance, but this reviewer questions the advisability of such early motion, preferring to obtain wound healing for two weeks and then to use a walking cast for another two to four weeks, with unprotected weight bearing in four to six weeks.]

Fernández [496] reports a case of tibiofibular diastasis fixed by a long wood screw through the fibula and into the tibia. This is a disabling and often unrecognized deformity which leads to serious disability if overlooked.

[ED. NOTE: The method of fixation has been used by this reviewer with satisfaction.]

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495. Muller, G. M.: Fractures of the Internal Malleolus, Brit. M. J. **2**:320 (Sept. 8) 1945.

496. Fernández, L. L.: Diastasis tibio-peronea: Tornillo de vitalio, Prensa méd. argent. **32**:1709-1711 (Aug. 31) 1945.

Nyström [497] describes a method for reduction and fixation of the displaced posterior malleolar fracture. A carpenter's awl is inserted through the achilles tendon; the fragment is engaged, reduced and held in position by the awl while a vitallium nail is driven in for fixation. If the ankle is dislocated, it must be reduced first, and then the procedure can be carried through a posterior window in the cast. It must be done promptly.

Perrigard [498] discusses posterior dislocation of the ankle with malleolar fractures and describes a so-called jujitsu hold to facilitate reduction. The illustrations must be seen adequately to visualize the method. He emphasizes the importance of a properly fitted cast for an adequate period (three months).

Barnes [499] discusses external malleolar fracture with some discussion of anatomy in reference to the various levels of fracture. He points out that treatment should be designed to (1) restore a proper weight-bearing line, (2) restore normal articular relations and (3) obtain painless motion. The result depends on (1) anatomic reduction and fixation, (2) normal tibiofibulotalar articulation and (3) restoration of muscle tone. He cites many errors commonly occurring in treatment of malleolar fractures and urges greater care and attention in this fracture.

Magnusson [500] is writing a series of articles on late results in malleolar fractures, the present review covering one [500] and part of another.[501] The former concerns late results in the supination or inversion type of fracture treated nonoperatively. Supination fractures are described, and the author states that 127 patients with this type of fracture were treated. Sixty-one of these patients came in for follow-up examination, both clinical and roentgenologic. Treatment occurred during the period from 1931 to 1940. In the group of 61 patients, 24.6 per cent reported subjective symptoms, but all the patients were following their regular occupation. There were 4 cases of varus position, all belonging to the bimalleolar group, but no case of valgus position was observed. Widening

497. Nyström, G.: Contribution to Treatment of Fractures of Posterior Border of Tibia by Malleolar Fractures, Acta radiol. **25**:672-678, 1944.

498. Perrigard, G. E.: Reduction of Posterior Dislocation of Ankle Complicated by Fracture of Distal End of Tibia and Fibula, Canad. M. A. J. **52**: 42-44 (Jan.) 1945.

499. Barnes, H. A.: The External Malleolar Fracture, U. S. Nav. M. Bull. **44**:509-514 (March) 1945.

500. Magnusson, R.: On the Late Results in Non-Operated Cases of Malleolar Fractures: Fractures by Supination Together with Survey of the Late Results in Non-Operatively Treated Malleolar Fractures, Acta chir. Scandinav. **92**:259-277, 1945.

501. Magnusson, R.: On the Late Results in Non-Operated Cases of Malleolar Fractures: Clinical-Roentgenologic-Statistical Study; Fractures by External Rotation, Acta chir. Scandinav. (supp. 84) **90**:1-136, 1944.

of the fork does not occur in fractures by supination. The author has, on the other hand, been able to show that a rupture of the syndesmotic ligament may occur in bimalleolar fractures with great varus dislocation. Arthrosis deformans, localized only in the ankle joint of the injured side, was found in 4.5 per cent of the unimalleolar fractures (follow-up examination in 44 cases) and in 64.7 per cent of the bimalleolar fractures (follow-up examination in 17 cases). A comparative survey of the late results in cases of malleolar fracture treated nonoperatively is given in the last section of the study. Of 412 patients with malleolar fracture examined in follow-up study, 32.5 per cent suffered from subjective symptoms. There was no difference in frequency between men and women. Age did not seem to have anything to do with the subjective symptoms. Their frequency was, however, greater in the more severe than in the slight fracture. There was a statistical probability that deforming changes in the ankle joint might give rise to subjective symptoms more frequently than would cases without such changes. The post-traumatic valgus foot is probably due to insufficiency in the medial ligaments. Roentgenologically verified arthrosis deformans in the ankle joint of the injured side was found in 45.7 per cent of the cases. Not only anatomic changes but also age played a part in the onset of the deforming changes. The periods of immobilization in the cases under discussion were too short. It was also found that the patients have been permitted to bear weight on the injured foot too early. Finally, the author gives the periods of immobilization suitable for the different types of fracture. Chapter 6 of the second study [501] describes the late results in cases of fracture by external rotation. This group is composed of 386 cases, with after-examination in 211 (51.2 per cent). The findings in after-examination are summarized in chapter 7. They reveal no difference between men and women as to frequency of subjective symptoms, and the patients with and without subjective symptoms were of the same average age. There was no significant difference in frequency of these symptoms in the groups with and without posterior fragment. Valgus of the foot at the injured side only was observed in 29 of the 211 cases, while valgus at the uninjured side only was found in 4 cases. This would seem to indicate that valgus deformity at the injured side is due, at least in part, to the fracture. Arthrosis deformans, at the injured side only, was observed in 104 cases (49.3 per cent). There was no difference between men and women with reference to frequency of arthrosis deformans. Noteworthy limitation of working capacity was noted in only 2 cases (0.95 per cent). Arthrosis deformans was more frequent in cases in which there was injury to the anterior tibial joint (partial diastasis) than in cases in which such injury did not occur. The earlier assumption that age plays a role in the development of unilateral arthrosis deformans was verified for all the groups of fractures by external rotation, when calculating the average age. The observations with reference to deforming

changes seemed to show age as a significant factor: In the 85 cases without deforming changes the average age of the patients at the time of accident was approximately 35 years, and at the time of after-examination, about 40.5 years. In the 104 cases with unilateral deforming changes, the average age at the time of accident was 43.9 years, and at the time of after-examination about 49.8 years. In the 22 cases with bilateral deforming changes the two age figures were 56.4 and 63.2 years.

Holstein [502] discusses fractures due to explosive effect of blast from below decks, citing the frequency of nerve or vascular changes. He stresses the importance of repeated paravertebral block in these cases.

Fractures in the Foot.—Calcaneum Fractures: Harris [503] and Poborsky [504] in separate articles discuss various types of fractures of the calcaneum and present their favorite methods for reduction and fixation, both favoring multiple pins if displacement is severe.

Kiaer and Anthonsen [505] in an extensive article report 27 calcanean fractures with arthrodesis in the talocalcanean joint and in Chopart's joint (triple arthrodesis) treated from 1936 to March 1941. Five patients were omitted from consideration in the article for various reasons (circulatory disturbances in 1 case and treatment too recent or incomplete at time of writing in 4 cases) leaving a total of 22 cases, with an average fracture age of 9.4 months. Operation was performed on account of protracted complete inability to work, pain in the foot and reduced mobility in the talocalcanean joint. Prognosis was found to be particularly poor with conservative treatment. Some details of operative technic are given. After-treatment is as follows: At the end of four weeks, the padded plaster bandage is replaced by an unpadded walking cast for eight weeks, and then by a foot brace for four to twelve months. The authors question the value of the foot brace. No physical therapy was used beyond submarine massage on the days when the patient did not stand on his foot after removal of the last plaster bandage and before the foot splint or arch support had been made. The only complication found was an insignificant necrosis of the edges of the wound in 2 cases. Operative results were as follows: In all cases a bony ankylosis of the talocalcanean joint was obtained; in 2 cases the ankylosis of Chopart's joint was only partial, but this did not impair the function of the foot. Clinical results, as observed in March 1941, showed that 19 old fractures had been treated with arthrodesis and that the result was excellent in 10 cases and good in 5; there was improvement in 3 and no change in 1.

502. Holstein, A.: Concussion Fractures and Dislocations Aboard Small Craft, U. S. Nav. M. Bull. **44**:790-792 (April) 1945.

503. Harris, R. I.: Fractures of Os Calcis: Improved Methods of Treatment, Bull. Vancouver M. A. **21**:43-47 (Nov.) 1944.

504. Poborsky, R. W.: Calcaneum Fractures, Indust. Med. **13**:991-992 (Dec.) 1944.

505. Kiaer, S., and Anthonsen, W.: Calcaneum Fractures Treated with Arthrodesis, Acta chir. Scandinav. **87**:191-213, 1942.

In addition, 3 recent fractures were treated, 2 with excellent results and ability to work at the end of six to eight months, and 1 with good result and ability to work four months after operation. Average age of the patient at the time of operation was 37 years (minimum 17 years, maximum 55). Average period of preoperative disablement was 9.4 months. Postoperative disablement, including the period of treatment, in cases with excellent result (12), was approximately six months (minimum four, maximum twelve, and in cases with good result (6) approximately the same. In the cases with improvement (3) the period of disability was long (twenty-four, eight and twenty-five months), and 1 patient, whose condition was unchanged after operation, was still unable to work at the time of writing. The period of treatment was approximately one hundred days. Working capacity in relation to the age of the patient showed that there was no definite relation between the functional result and the age of the patient. The same was true of the period of postoperative disability. Mobility of the ankle was somewhat reduced in about half of the cases and greatly reduced in 3 cases. Muscular atrophy of the leg involved was noted in all patients to the extent of 1 to 2.5 cm.

Fatigue, Strain and March Fracture: Leveton [506] reports 259 fatigue fractures in the metatarsals (by far the most common site) treated at one station hospital. His conclusions from this large group of cases are as follows:

> 1. Metatarsal march fracture is primarily an occupational disease of soldiers. 2. The author believes that metatarsal march fractures are caused by fatigue of the peroneus longus and tibialis posticus muscles. 3. March fractures are more properly termed fatigue fractures. There is no basis for the belief, as some authors have indicated, that metatarsal march fractures are due to spasm and overactivity of the interossei muscles. 4. The presence of an atavistic foot as an etiological factor of metatarsal march fracture is greatly over-rated. 5. All of the metatarsal march fractures in this series occurred in soldiers with normal feet, or in cases of slight degree of pes planus and in cases of pes cavus. Not a single case of severe pes planus was encountered. 6. Pre-induction occupation of the soldier does not appear to be a decisive factor except so far as the tolerance of fatigue may be concerned. 7. The thinness of the metatarsal bone plays no important role in the etiology of metatarsal fractures. 8. In the 259 fractures all age groups from 18 to 38 were involved, but the 18 and 19 year old group were chiefly affected. 9. March fractures of the metatarsals involved all bones of the metatarsal segment but chiefly the second and third of the right foot. 10. Twenty-three cases of multiple metatarsal march fractures were encountered. 11. Fractures of the metatarsal bone involved 2.35 per cent of 10,953 cases seen by the orthopedic surgical section at the author's station hospital.

Scott [507] reports 58 fatigue fractures from a Naval training center and advances the theory that a common predisposing cause is a thyroid defi-

506. Leveton, A. L.: Metatarsal March (Fatigue) Fractures, Am. J. Surg. **70**:49-57 (Oct.) 1945.

507. Scott. W.: March Fractures, Surg., Gynec. & Obst. **81**:525-529 (Nov.) 1945.

ciency. Forty-eight of his 58 cases were studied metabolically. He recommends five to ten days of bed rest with thyroid if indicated. The patient is then returned to duty with enough thyroid for nineteen days. No other treatment is used.

Kitchin and Richmond [508] report 2 fatigue fractures, 1 in the upper part of the tibia and 1 in the lower part of the femur. They point out that in certain stages such fractures may be confused with Ewing's or osteogenic sarcoma.

[ED. NOTE: The reviewer recalls a case many years ago seen in consultation regarding a recommendation of amputation of the foot because of "osteogenic sarcoma" of the second metatarsal. Investigation revealed a typical march fracture.]

Wolfe and Robertson [509] report 2 cases of stress fracture, 1 in the tibia and 1 in the femur. Both were diagnosed as a strain. The femoral fracture went on to complete fracture before the stress fracture was recognized.

Bingham [510] refers to 4 cases of stress fracture of the femoral neck reported by Henry and adds a case of intertrochanteric stress fracture with varus deformity.

Tortosa [511] reports 3 cases of stress fracture; in 1 of these cases the fractures were bilateral ischiopubic, involving a most unusual location.

OPERATIVE FIXATION OF FRACTURES

A. Medullary Nailing.—In the past three years, there has been a great revival of interest in, or a rediscovery of the use of, intramedullary nails for the fixation of fractures of the long bones. Forty years ago, Lambotte used a longitudinal wire to immobilize fragments of the clavicle. In 1920, Groves inserted an axial nail in a comminuted fracture of the femur. In 1924, Lambotte used intramedullary pins in the femur, the humerus and the metacarpals. Danis, in 1937, used longitudinal wires in the bones of the forearm, as did L. V. and H. L. Rush in this country. In 1940, Lambriduni used metal pins in the forearm and the femur and James Dickson reported similar experience. In recent textbooks, Bohler, Bancroft and Murray, Soeur, Bonnin and Watson-Jones describe this method of fixation of certain fractures of long bones.

Since 1942, the v-shaped stainless steel nail devised by Kuntscher has been widely used in Europe, and recent articles describe experience with

508. Kitchin, I. D., and Richmond, D. A.: Two Unusual Stress Fractures, Brit. M. J. **2**:214-215 (Aug. 18) 1945.

509. Wolfe, H. R. I., and Robertson, J. M.: Fatigue Fracture of Femur and Tibia, Lancet **2**:11-13 (July 7) 1945.

510. Bingham, J. A. W.: Stress Fracture of Femoral Neck, Lancet **2**:13-14 (July 7) 1945.

511. Rovira Tortosa, A.: Fracturas lentas o fracturas por sobrecarga; contribución clínica, Cir. d. ap. locom. **1**:362-369 (Oct.) 1944.

"Kuntscher nails." The principles are essentially those which have been described many times before, but much of the recent interest stems from the problems of comminuted gunshot fractures of the most recent war.

F. Martín Lagos [512] reported the use of this method in 14 cases. In the femur, the nail was introduced from the lower or the upper end. In the humerus a slightly curved nail was used. The author said that there is little danger of fat embolism and that in cases of infection the nail serves as a drain.

A. W. Fischer and R. Maatz [513] give a detailed report of their experience of medullary nailing in over 200 cases. The more cases they did, the more they saw need for special instruments to insert and to remove the nails and better protection of the hands from exposure to roentgen rays. Also they found that many nails of many sizes were necessary to provide the optimum fixation. If nails did not fit tightly in the medullary space there was danger of rotation of fragments, which necessitated the use of casts or splints. Corrosion of the nails occurred in some of the early cases due to the use of improper metal. Splitting of the bone, migration of the nail out of position, breaking of the nail and late atrophy of the bone were some of the serious unfavorable results. The article stresses the minute details of treatment from "time of operation" to "removal of nail" and is the best of the recent reports on this subject.

H. Griessmann and H. Reich [514] performed experiments on animals to compare the healing callus of fractures treated by plaster casts with those treated by medullary nails. When nails were used, the callus extended for a greater distance on each side of the fracture site than when casts were used. The callus following medullary nailing was of "higher structural value" than that seen after fixation by plaster cast. After medullary nailing, the forces of traction and rubbing were eliminated and only pressure force remained. This, the authors felt, was more conducive to the development of strong solid union.

[Ed. Note: All this may be so, but the shearing force possible when the fragments rotate slightly about the nail is much more injurious to callus than traction.]

The insertion of medullary nails when fragments are displaced is far from easy, and K. Herzog [515] has described a kinked metal tube to be used to lever the fragments into position. Two metal sleeves are

512. Martín Lagos, F.: El enclavijamiento medular de Küntscher, Rev. españ. cir., traumatol. y ortop. **1**:1-18 (July) 1944.

513. Fischer, A. W., and Maatz, R.: Weitere Erfahrungen mit der Marknagelung nach Küntscher, Arch. f. klin. Chir. **203**:531, 1942.

514. Griessmann, H., and Reich, H.: Vergleichende Untersuchungen über den Ablauf der Knochenbruchheilung bei der Marknagelung und bei den mit Gipsverband behandelten Frakturen, Arch. f. klin. Chir. **205**:455, 1944.

515. Herzog, K.: Verbessertes eigenes Hebelgerät zum Ausgleich der Seitenverschiebung bei Brüchen der langen Röhrenknochen zur Anwendung bei der Marknagelung, Zentralbl. f. Chir. **70**:1656 (Nov. 13) 1943.

maneuvered over the fragments to aline them before the nail is inserted. The article contains five drawings to illustrate the device and three roentgenograms to demonstrate its use.

Because it is necessary that medullary nails fit tightly into the bone, R. Maatz [516] has developed a wedge-shaped piece of metal which is driven in between two flat nails that are previously inserted. The wedge has "stepped" edges which engage the substantia spongiosa to prevent slipping.

[ED. NOTE: This seems to be making an easy operation difficult, and the fact that three nail heads protrude from the wound would tend to increase the chance of infection.]

A. Vogl [517] reports 7 cases in which medullary nailing was used in comminuted gunshot fractures and in pseudarthroses of fractures of long bones.

[ED. NOTE: His roentgenograms show good union, but others have found this method useless in the repair of ununited fractures.]

In C. Rocher's experience [518] with 43 cases of medullary nailing there were three points emphasized: the need for a large assortment of nails to insure the right nail for the right case, the difficulty of securing nails of the proper quality of metal and the great difficulties of removing the nails after the fractures had healed. The author, however, was enthusiastic about this method of treatment of fractures and felt that it was "the method of osteosynthesis of the future."

M. García Portela [519] discusses all the background of Kuntscher nailing and reviews 457 cases found in the literature. His 10 personal cases include 3 corrective osteotomies (2 of the femur, 1 of the ulna) of old fractures where intramedullary nails were satisfactory devices for postoperative fixation.

L. Sierra Cano and E. Rodríguez Valdés [520] report the use of medullary nails in 13 cases including fresh fractures, pathologic fractures, compound fractures and ununited fractures.

W. Heim [521] points out several disadvantages of intramedullary nailing: It is difficult to place the patient in proper position for reduc-

516. Maatz, R.: Ueber Formschlussigkeit bei der Küntscher-Nagelung, Zentralbl. f. Chir. **70**:1641 (Nov. 13) 1943.

517. Vogl, A.: Die Marknagelung in der Wiederherstellungschirurgie, Zentralbl. f. Chir. **70**:1649 (Nov. 13) 1943.

518. Rocher, C.: L'enclouage centro-médullaire des os longs, Presse méd. **53**: 94-95 (Feb. 24) 1945.

519. García Portela, M.: El enclavamiento medular de Kuenscher, Rev. clín. españ. **15**:1-18 (Oct. 15) 1944.

520. Sierra Cano, L., and Rodríguez Valdés, E.: Los problemas mecánicos y biologicos del enclavijamiento medular de Küntscher, Cir. d. ap. locom. **2**:193-229 (July) 1945.

521. Heim, W.: Ergebnisse ans der Nagelungsbehandlung bestimmter Knochenbrüche, Deutsche med. Wchnschr. **70**:491 (Sept. 1); 524 (Sept. 15) 1944.

tion of the fracture and insertion of the guide wire. Incorrect introduction of the nail is easy, and replacement of the fragments is often difficult. Nails must be chosen exactly for proper length, thickness and shape in the case of each fracture. Insertion of nails that are too thick may break the bone, and extraction of the nails may also endanger the bone. The author concludes with a detailed analysis of his 23 cases and states that "the surgeon must be very selective in his procedure in the individual case."

Under unfavorable war conditions, B. M. Tordoir and E. J. Moeys [522] used intramedullary nails in 21 cases of closed fractures and 10 cases of compound fractures. While they felt that intramedullary nails were best adapted to transverse fractures of the shaft, they also applied the method to spiral and comminuted fractures. They were of the opinion that this method promised hope in the immobilization of compound fractures.

It is too early to predict the future for intramedullary nailing, and sufficient experience has not yet been gained. Nevertheless, the method holds promise in certain comminuted fractures where there are several long fragments that cannot be immobilized by the usual methods of treatment. It may also prove superior to some forms of plating operations when the latter require too much stripping of periosteum from the site of the fracture.

B. Devices for External Fixation.—The names of Lambotte, Haynes, Anderson, Stader and many others have been identified with apparatus which was designed to immobilize fractures without introducing permanent metal plates and screws into the bone. The impelling motives in each case were to try to avoid infection, to provide early articular motion and to eliminate "electrolytic osteitis" from plates and screws. How successfully these aims have been achieved is still open to question.

C. F. Ferciot [523] cites the disadvantages of external fixation: the need for special apparatus, the special skill required for insertion of pins, additional damage to soft tissues, the temptation to keep improving the position and irritation of the soft tissue about the pins. The advantages of the method are: accurate reduction with minimal trauma, maintenance of reduction, ease of care of soft tissues and possibility of early articular motion. In 22 of his 48 cases, in young adults, good bony union was secured, though the healing time was not materially affected. Although early weight bearing was not encouraged, articular motion shortened the convalescence and minimized atrophy of the muscles.

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522. Tordoir, B. M., and Moeys, E. J.: Treatment of Certain Types of Fractures with V2A Steel Nail in Medullary Cavity (Küntscher Method), J. A. M. A. **128**:792-794 (July 14) 1945.

523. Ferciot, C. F.: The Use and Abuse of External Skeletal Fixation, Nebraska M. J. **30**:55-57 (Feb.) 1945.

E. Marques Pôrto [524] considers the Roger Anderson method of treating fractures of the shaft of the femur a notable advance.

A more detailed study by I. E. Siris [525] leads to the conclusion that "in 80 cases of external mechanical pin fixation of fractures, the high incidence of discharge from the pin sites (46 per cent), of osteomyelitis of the pin sites with persistence of discharge long after the fracture had united (22.5 per cent), and of deaths (10 per cent) should preclude the further use of the method as a routine procedure for fractures of the long bones." The author feels, furthermore, that much emphasis has been laid on ambulation and articular motion and that these features should not be the motivating factors for the use of external mechanical pin fixation.

[ED. NOTE: These condemnatory opinions are of much value, since they are expressed by one who has had a large experience with external fixation.]

In England, E. H. Wilson [526] noted that patients who sustained fractures of the femur were disabled more than a year and always suffered some degree of limitation of motion of the knee joint. The 350 patients treated at the American Hospital in Britain by external fixation were generally much better than the ones treated in the Army. Still the advantages and disadvantages of external fixation tended to neutralize each other except when treatment was well supervised by trained personnel.

For the protection of projecting pins in the bone, H. D. Caylor and L. Witwer [527] have described fiber collars with set screws which can be attached over the pins and thus cover the sharp ends.

[ED. NOTE: This is one way of overcoming the tendency for pins to move back and forth in the bone and thereby to spread infection.]

C. Devices for Internal Fixation.—The use of metallic internal fixation in fresh fractures continues to arouse interest even after three decades of discussion on the subject. Nowadays the articles tend more to descriptions of technical details or of newly developed metals rather than to questions of the advisability of open reduction.

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524. Marques Pôrto, E.: Novo método de tratamento ambulatório das fraturas, Rev. med.-cir. do Brasil **52**:679-685 (Sept.-Oct.) 1944.

525. Siris, I. E.: External Pin Transfixion of Fractures: Analysis of Eighty Cases, Ann. Surg. **120**:911-942 (Dec.) 1944.

526. Wilson, E. H.: Functional Treatment of Fractures and Other Injuries, Arch. Phys. Med. **26**:349-352 (June) 1945.

527. Caylor, H. D., and Witwer, L.: Device to Protect the Projecting End of Kirschner Wires, Steinmann Pin or External Fixation Pins, Am. J. Surg. **70**:133 (Oct.) 1945.

In Russia, V. V. Troitskiy and D. N. Tsitrin [528] prepared an alloy of magnesium with a small amount of cadmium to increase solidity. Plates, screws, clamps and nails of this metal were placed in animals, where they slowly dissolved without altering the blood levels of magnesium.

[ED. NOTE: Magnesium alloys have been utilized many times previously and are supposed to possess the virtue of slowly dissolving in the body. The great drawback is that surrounding bone is "dissolved" at the same time.]

D. B. Cobb [529] places oblique Kirschner wires across fractured long bones and incorporates the projecting ends in the cast. He feels that this causes less disturbance of the periosteum than any other method of fixation.

C. S. Venable [530] emphasizes that after plates have been placed on long bones the fragments are more securely anchored if a long transfixtion screw is placed obliquely across the line of fracture.

In a general discussion on fixation of fractures Dr. Cubbins [531] emphasized that fractures of the hip must be perfectly reduced and firmly secured to obtain satisfactory results. Dr. Lewin could see no advantage in unpadded casts or reason to change from "properly padded, properly applied casts to the unpadded ones." In considering the treatment of fractures of the humerus, Dr. Lewin characterized the hanging cast as "a gift from heaven."

A. L. Murphy [532] gives a brief review of the history of internal fixation and states that there is a swing to more open reductions. He thinks that better understanding of the need for prevention of muscle atrophy is responsible for this. Also the introduction of vitallium has made available a material which is better tolerated by the tissues than any of the other new agents for internal fixation.

The details of technic of applying plates to bones is well outlined by W. F. Lyon.[533] His most significant point is the emphasis on need for exact centering of the screws in the holes in the plate.

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528. Troitskiy, V. V., and Tsitrin, D. N.: Absorbable Metallic Alloy, "Osteosintezit" as Material for Fixation of Fractured Bones, Khirurgiya, 1944, no. 8, pp. 41-44.

529. Cobb, D. B.: A Simple Method of Fracture Fixation with the Kirschner Wire, North Carolina M. J. **6**:92-96 (Feb.) 1945.

530. Venable, C. S.: The Use of Transfixion Screws, Am. J. Surg. **67**:145-154 (Feb.) 1945.

531. Slobe, F. W.; Lewin, P.; Cubbins, W. R.; Diehr, A. H., and Wellmerling, H. W.: Fixation of Fractures: Panel Discussion, Indust. Med. **14**:120 (Feb.) 1945.

532. Murphy, A. L.: The Present Status of the Internal Fixation of Fractures, Canad. M. A. J. **52**:582-587 (June) 1945.

533. Lyon, W. F.: Technic of Plating Long Bone Fractures, S. Clin. North America **25**:99-110 (Feb.) 1945.

[ED. NOTE: Dr. Lyon has been interested a long time in the question of holding power of screws in bone, and his opinions on this subject are backed by much authority.]

Ulises Sosa de Quesada and Luis Saiz Navarro [534] describe various methods of treatment of 96 fractures of the shaft. Their results were best in those cases in which treatment was with vitallium plates and screws.

Gerard Saint-Onge [535] recommends suturing of bones with silkworm gut or bronze wire because of "war shortage of materials."

[ED. NOTE: War shortage is about the only justification for bone sutures. This method was abandoned many years ago because it did not provide sufficiently secure fixation.]

R. M. Yergason [536] advises placing Kirschner wires obliquely across fractures while leaving the ends projecting through the skin. For fractures of the patella and the olecranon he prefers heavy silver wire. He also discusses the relative merits of vitallium, tantalum and stainless steel.

FRACTURES OF THE SPINE AND THE PELVIS

War wounds of the pelvis are described by L. G. Lewis,[537] and he cites the types of treatment needed when urethra, bladder and rectum are injured. Suprapubic cystotomy and colostomy are performed early; hemostasis is essential as well as repair of visceral defects. Early drainage of the bladder to prevent extravasation is probably the most important life-saving measure in these cases.

Walter Carruthers,[538] who has written much on fractures of the pelvis, states that in 16 per cent of cases of fracture of the pelvis there is accompanying injury to soft tissue. In 10 per cent there are injuries to the urinary tract. He feels that fragments must be perfectly restored in women to prevent interference with child bearing. In his experience with 66 cases, he has been able to effect excellent reduction with the turnbuckle casts for traction and lateral separation of the thighs.

Another discussion of the turnbuckle cast treatment for fractures of the pelvis, by C. M. Silver and H. W. Rusbridge,[539] concerns its

534. Sosa de Quesada, U., and Saiz Navarro, L.: Concepto actual en el tratamiento de las fracturas diafisarias de los huesos largos, Cir. ortop. y traumatol., Habana **12**:3-23 (Jan.-March) 1945.

535. Saint-Onge, G.: Procédé simplifié d'ostéo-synthèse, Union méd. du Canada **74**:599-604 (May) 1945.

536. Yergason, R. M.: Metallic Fixation of Fractures by Use of More Recent Methods and Appliances, Connecticut M. J. **9**:276-280 (April) 1945.

537. Lewis, L. G.: Cases of Severe Pelvic Injury, Tr. South. S. A. (1944) **56**:86-93, 1945.

538. Carruthers, W.: Anatomic and Functional Reductions of Fractures of the Pelvis, Am. J. Surg. **69**:39-46 (July) 1945.

539. Silver, C. M., and Rusbridge, H. W.: A Treatment for Displaced Fractures of the Pelvis, J. Bone & Joint Surg. **27**:154-156 (Jan.) 1945.

use in the Army in North Africa. With makeshift web straps, enough tension could be obtained to reduce overriding fragments perfectly.

In 45 per cent of pelvic ring fracture, J. G. Bonnin [540] found evidence of fractures of the sacrum. Most of these involved the upper foramina with symptoms referable to the first and second sacral nerves —tingling over the outer side of the foot, weakness of the hamstrings and muscles of the calf and diminution of ankle jerk. Recovery was slow and some impairment of gait persisted in a number of cases.

S. N. Deboo [541] says that fluoroscopy is inaccurate in making diagnostic studies of injured backs. Even good roentgenograms are sometimes misinterpreted because of persistent epiphyses or partial ossifications of the anterior longitudinal ligament that may be confused with true fractures.

A special sprain fracture of the spine is described by J. H. Annan [542] in British prisoners of war who were used by the Germans to shovel sand. Fifteen cases of "shoveler's fractures" were observed wherein the sixth and seventh cervical spinous processes were fractured spontaneously after heavy labor. Undernutrition and excessive fatigue were probably contributing factors. Recovery was complete after conservative rest therapy.

Fractures of the spine in "metrazol shock," according to Alberto Fernández Saralegui,[543] are really avulsion fractures. Preliminary spinal anesthesia, as recommended by Hamsa and Bennett, is advisable to prevent the severe strains on the spine.

A new type of corset for the treatment of spinal fractures has been developed by G. Sajgo.[544] The ordinary body cast is used six weeks to "rest the spastic musculature of the back." Then a corset is applied which is hinged in the middle to allow gradual correction while at the same time permitting light treatments and massage.

The nursing care of patients with fractures of the spine and injury of the cord is explained by L. A. Mount.[545] She emphasizes the irreparable harm which can be done patients by improper handling and points out the advantages of skeletal traction on the skull. Prevention of

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540. Bonnin, J. G.: Sacral Fractures and Injuries to the Cauda Equina, J. Bone & Joint Surg. **27**:113-127 (Jan.) 1945.

541. Deboo, S. N.: Radiological Aspect of Fractures of the Spine Based on an Analysis of Two Hundred and Fifty-Four Cases of Injury to the Back, M. Bull., Bombay **12**:353-357 (Dec. 16) 1944.

542. Annan, J. H.: Shoveler's Fracture, Lancet **1**:174-176 (Feb. 10) 1945.

543. Fernández Saralegui, A.: Fracturas por shock cardiazólico, Rev. Asoc. méd. argent. **58**:864 (Oct. 15) 1944.

544. Sajgo, G.: Ein neuer Typ von Redressement- und Entlastungsmieder, Ztschr. f. Orthop. **74**:309, 1943.

545. Mount, L. A.: Injuries of the Spinal Cord: Treatment of Injuries Associated with Fractures of the Spine, Am. J. Nursing **45**:101-103 (Feb.) 1945.

bedsores and supervision of bowel and bladder function are likewise well presented.

A new adjustable cervical spinal brace is described by Edwin Boldrey.[546] Since plaster of paris casts are bulky and uncomfortable and are not particularly effective, this brace seems to offer more endurable support to the neck. An aluminum cup is shaped about the occiput and as far forward as the ears. This is attached to the shoulder and trunk portion of the brace by a ball and socket joint. Since no apparatus fits under the chin, the mandible is free, and this permits chewing and talking without effort. When properly fitted to the patient, this brace holds the head securely and yet does not cause any distressing discomfort.

The operative treatment of dislocations of the cervical part of the spine is discussed by R. J. B. McEwen and J. G. Bickerton.[547] In 3 cases in military hospitals, the dislocated facets were exposed and levered into position by direct pressure. Traction by skeletal tongs in the skull was maintained during the operation to prevent injury to the spinal cord. Afterward plaster casts were applied to be worn during convalescence.

[ED. NOTE: Rogers and others have shown that there is a great tendency to recurrence of dislocations of the cervical part of the spine even after they have been well reduced. Consequently they advised wiring the spinous processes at the time of the operation or inserting a bone graft.]

From the Mayo Clinic J. J. Hinchey and W. H. Bickel [548] reported 8 cases of fracture of the atlas. While this is a serious injury, it is fatal in only 10 per cent of cases. Often there is fracture of the skull or of the cervical part of the spine in addition. The anatomic features of the atlas are well explained in relation to the mechanism of the fracture, since there are few clearcut symptoms. Treatment is by head traction followed by the use of a plaster collar for six or eight weeks. Stiffness of the neck and occipital neuralgia are uncomfortable after-effects of this injury.

E. H. T Hambly [549] has similarly shown that fractures of the odontoid process of the axis are not so deadly as was once supposed. There may be simple cracks at the base of the odontoid process, fractures of the odontoid with dislocation of the axis, or hyperextension fracture-dislocations of both axis and atlas. The author reports a case of fracture-

546. Boldrey, E.: Supportive Immobilization of the Cervical Spine, Surg., Gynec. & Obst. **80**:107-108 (Jan.) 1945.

547. McEwen, R. J. B., and Bickerton, J. G.: Dislocations of the Cervical Spine Treated by Open Reduction, J. Bone & Joint Surg. **27**:679-682 (Oct.) 1945.

548. Hinchey, J. J., and Bickel, W. H.: Fracture of Atlas, Ann. Surg. **121**: 826-832 (June) 1945.

549. Hambly, E. H. T.: Fracture of the Odontoid Process: A Method of Fixation, Lancet **2**:851 (Dec. 30) 1944.

dislocation of the odontoid with paralysis which was successfully treated by traction and manipulation under anesthesia.

FRACTURE COMPLICATIONS: INJURIES TO NERVES

Peripheral nerve injuries with fractures are enumerated by E. S. Gurdjian and H. M. Smathers.[550] Their study is based on 53 cases: injuries to a radial nerve, 32 cases; to an ulnar nerve, 9 cases; to a median nerve, 3; to a peroneal nerve, 8, and to a sciatic nerve, 1. Early exploration of injured nerves is recommended, especially if the fractured bone is to be treated by open reduction. When the ulnar nerve is injured with fracture of the medial condyle of the humerus, the authors recommend prompt exploration and anterior transposition of the nerve. In compound fractures, it is now possible to do primary repair of nerves because of modern chemotherapeutic methods. The article possesses an excellent bibliography.

The importance of early treatment of nerve injuries is stressed by R. G. Spurling,[551] who was consultant in North Africa. Early in the European War, patients with injuries to bones and nerves were treated first for the fractures and then two to four months later were referred to the neurosurgeons for repair of the nerves. After such an interval, only 20 per cent of the cases had satisfactory outcome. In December 1944 a program was instituted for early treatment of injuries to nerves, and 300 patients were treated within six weeks after the accident. The results were much better, especially in the case of sutures of radial and sciatic nerves. The poorest results were obtained in sutures of the brachial plexus, the median and the ulnar nerve, because of the mixed nature (motor and sensory) of these nerves.

COMPOUND FRACTURES

The National Research Council's Project on Contaminated Wounds, reported by F. L. Meleney and A. O. Whipple,[552] summarized the results of treating 926 wounds involving soft tissue, 674 compound fractures and 591 burns, a total of 2,191 injuries treated at six centers throughout the United States over a twenty-two month period. The chief factors concerned with the development of infection in soft tissue wounds and compound fractures were found to be (1) degree and extent of damage to

550. Gurdjian, E. S., and Smathers, H. M.: Peripheral Nerve Injury in Fractures and Dislocations of Long Bones, J. Neurosurg. **2**:202-219 (May) 1945.

551. Spurling, R. G.: Early Treatment of Combined Bone and Nerve Lesions, Bull. U. S. Army M. Dept. **4**:444-446 (Oct.) 1945.

552. Meleney, F. L., and Whipple, A. O.: Statistical Analysis of Study of Prevention of Infection in Soft Part Wounds, Compound Fractures, and Burns with Special Reference to Sulfonamides, Surg., Gynec. & Obst. **80**:263-296 (March) 1945.

soft tissue, (2) degree of gross contamination by foreign material, (3) duration of time between injury and surgical care, (4) nature of bacterial flora in wounds and (5) care and thoroughness with which devitalized tissue, foreign bodies and gross contamination are removed. The first four of these factors applied in burns; yet most important was the extent and depth of the burn.

The prophylactic use of sulfonamide compounds, locally or systemically or in combination, failed to reduce the incidence or severity of local infections in wounds or burns. The development of infection was not delayed, nor were pathogenic organisms eliminated from the wounds by the use of sulfonamide drugs. Sulfonamide compounds did minimize the spread of local infection, thereby reducing septicemia and death; however, this was accomplished by systemic drug therapy when infection developed in the controls as readily as when the drug was used prophylactically.

Although the results were somewhat disappointing, so far as the workers had hoped to find something which would prevent infection in these wounds, their observations indicated that the prevention of infection in both civilian and war wounds rests on the well known surgical principles of removal of devitalized tissue and contaminants with rapid restoration of normal functioning of the involved part. Such factors are beyond the scope of sulfonamide drugs.

A number of articles on the management of compound fractures and other war wounds appeared in 1945, depicting a pronounced evolution in the management of these cases. M. Sulamaa [553] discussed the advantages of the Orr method and its counterpart, the Löhr method, used in 75 war fractures with a mortality of 5.3 per cent and one amputation. He stressed the importance of careful examination for other wounds, especially vascular injuries, before application of the closed plaster cast and warned against the possibility of the formation of abscesses beneath the closed plaster. He acknowledges the objection of the offensive odor and recommends that the closed plaster be discontinued in the late stages unless absolutely necessary.

Numerous articles during 1945 described the advent of delayed closure of war fractures and the use of penicillin as an adjunct to treatment. R. W. Hendry, W. C. Gledhill and B. H. Price [554] reported their results in the management of 465 soft tissue wounds and 128 open fractures with local and systemic administration of penicillin, followed by secondary closures of these wounds; the result was 87 per cent closures

553. Sulamaa, M.: Combination of Ointment Dressings and Casts in Therapy of Gunshot Fractures, Acta chir. Scandinav. **89**:483-498, 1944.

554. Hendry, R. W.; Gledhill, W. C., and Price, B. H.: Treatment of Battle Casualties: Two-Stage Operation, Lancet **1**:618-621 (May 19) 1945.

in compound fractures at the end of six weeks. They feel that the local instillation of penicillin in the site of the fracture is of value.

F. H. Bentley and others [555] reported a series of 62 compound fractures treated by secondary closure (on the sixth day, on the average) combined with penicillin therapy. This method was successful in 58 cases with primary union of soft tissue and bone and in 2 other cases in which a second operation for removal of a foreign body was followed by union. In half of the 62 cases there was only local administration of penicillin, and in the remainder there was a combination of local and systemic administration of penicillin without appreciable difference in the success of healing in the two groups. Bentley and his co-workers stress the importance of surgical therapy when combined with penicillin, especially the removal of foreign bodies and complete cutaneous closures.

E. A. MacNaughton [556] reports the use of early secondary closure in the management of 10 compound fractures of the femur received during the Normandy invasion. He stresses the importance of (1) preoperative preparation of the patient consisting of rest, transfusions, administration of penicillin and sulfonamide drugs and noninspection of the wounds, (2) early reduction of the fracture, (3) early and complete closure of the wounds based on clinical appearance of the wound rather than on bacteriologic survey and (4) maintenance of reduction and fixation in plaster of paris spica.

J. A. MacFarlane [557] comments on the change in management of war fractures during the past five years from the closed plaster methods of Trueta to delayed closure of wounds in 90 per cent of all compound fractures with saving of life and limb and shortening the period of hospitalization. He points out that in an unpublished report from Italy equal success was obtained in two groups, one receiving prophylactic doses of penicillin and the other either inadequate amounts or no penicillin. MacFarlane credits much to the mobile surgery and shock teams and feels that, although penicillin plays its important part, the role of good surgical treatment cannot be overlooked.

[Ed. Note: The good results obtained in this type of war wounds were due chiefly to the use of good surgical judgment and the generally excellent type of surgical skill displayed in their management.]

The controversial subject of excision of wounds and resection of joints in managing war fractures was presented in several papers mainly

555. Bentley, F. H., and others: Treatment of Compound Fractures by Early Wound Suture and Penicillin, Lancet **1**:232-236 (Feb. 24) 1945.

556. MacNaughton, E. A.: Early Wound Closure and Treatment in Plaster of Ten Compound Fractures of Femur from Normandy Front, J. Canad. M. Serv. **2**:237-247 (March) 1945.

557. MacFarlane, J. A.: Compound Fractures in War, 1944, Lancet **1**:135-138 (Feb. 3) 1945.

by Russian surgeons. S. O. Portugalov [558] recommended removal of all infected bone, including the joints involved, close to the limit of sound tissue, thereby saving the uninvolved distal portion of the limb. By resection the infection is removed, and the defect in the bone can be restored later by bone grafts. The author considered the resulting extremities following excision of joints and repair much better than the best prosthesis.

Another Russian, S. R. Mirotvortsev,[559] recommends conservative-expectant treatment in wounds involving joint and synovial membrane. With failure of conservative measures he recommends wide arthrotomy and recommends resection of the joint if the pathologic process progresses. Immobilization in unpadded plaster casts is recommended routinely.

In a compact article on the treatment, prognosis and end results of managing war fractures, O. Wustmann [560] warns against resection of joints for empyema, which is "always managed by operative drainage of the joint."

H. von Haberer [561] from personal experience gained in World Wars I and II states that he is in favor of resection of joints in selected cases but at various times has opposed this practice. He considers resection of an infected joint unquestionably indicated in cases in which the infection constitutes danger to life should there be reason to believe that a halfway useful extremity will be the result. If the resection needs be so extensive that the extremity loses its functioning capacity, the author feels that amputation is preferable, especially in the lower extremity.

[ED. NOTE: Resection of wounds and joints is not considered a procedure of choice in the United States.]

H. E. Branch [562] states that bullet fractures of the long bone require more careful treatment than any other serious fracture. His article stresses conservation in débridement and management of these fractures and points out that fragments attached to periosteum and soft tissues act as "struts" or live bone grafts for the restoration of the shaft of the

558. Portugalov, S. O.: Conservative Operations on Extremities Instead of Amputations and Exarticulations: New Principle of Surgical Therapy of Septicopurulent Fractures, Khirurgiya, 1944, no. 11, pp. 64-70.

559. Mirotvortsev, S. R.: Clinical Aspects and Therapy of Gunshot Wounds of Large Joints, Sovet. med. (no. 7-8) **8**:8-10, 1944.

560. Wustmann, O.: Schussbrüche der Gliedmassen, Deutsche med. Wchnschr. **70**:243 (April 28) 1944.

561. von Haberer, H.: Zur Frage der Gelenkresektion nach Schussverletzungen, Chirurg **15**:729 (Dec. 15) 1943.

562. Branch, H. E.: Bullet Fractures of Long Bones, J. Bone & Joint Surg. **27**:227-232 (April) 1945.

bone. Removal of readily accessible nonmetallic foreign bodies is urged, but too extensive searching may do more harm than good.

O. Mayr [563] calls attention to the fact that war fractures often heal in poor position and recommends the wedging of casts to correct angulation and restore proper alinement of the fragments.

W. F. Stanek and W. C. Peterson [564] warn against comparison of results in treating civilian type compound fractures and war fractures because of the difference in surrounding circumstances. They stress the importance of reestablishment of articular motion and recommend the cooperation of orthopedic surgeons, plastic surgeons and neurosurgeons at special centers for best results in compound fractures.

An extensive article on the treatment of gunshot fractures was published by Oscar Hampton,[565] consultant in North Africa. Under war conditions statistical studies were impossible, though there were few infections and no serious sequelae from surgical treatment overseas. Reductions were more accurate than might be expected because inadequate reductions were not tolerated. Internal fixation of fractures with vitallium plates was performed when necessary to hasten recovery of articular motion. Elaborate care of wounds led to a high proportion of primary unions in cases in which sutures were done immediately.

M. Cleveland and J. A. Grove [566] discuss closure of compound wounds on the basis of their experience with 2,393 cases. "Delayed primary closure" caused 93 per cent to heal before the patients left the hospital. Success of this operation depended on early and adequate débridement of the wound, rapid evacuation of the wounded to permanent rear medical installations, the use of penicillin and sulfonamide drugs and transfusions of whole blood.

A general review of war wounds was given by P. D. Wilson.[567] He stated that improved treatment of shock with plasma and whole blood was most valuable in preparation for surgical treatment. There was a swing away from the Orr technic of using no dressings, and earlier closure of wounds became the rule. Loss of bone was repaired by bone grafts fastened with vitallium screws.

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563. Mayr, O.: Einfache, unblutige Korrektur schlecht stehender Frakturen im Kriege, München. med. Wchnschr. **90**:571 (Oct. 8) 1943.

564. Stanek, W. F., and Peterson, W. C.: Compound Fractures Occurring in the Army: Factors Influencing Treatment, Am. J. Surg. **67**:333-341 (Feb.) 1945.

565. Hampton, O. P., Jr.: Reparative Surgery of Compound Battle Fractures in the Mediterranean Theater of Operations, Ann. Surg. **122**:289-332 (Sept.) 1945.

566. Cleveland, M., and Grove, J. A.: Delayed Primary Closure of Wounds with Compound Fractures, J. Bone & Joint Surg. **27**:452-456 (July) 1945.

567. Wilson, P. D.: Treatment of War Injuries of the Skeletal System, Am. Rev. Soviet. Med. **2**:395-406 (June) 1945.

An interesting study of the effects of sulfonamide drugs in compound fractures was reported by M. J. Wilson and A. R. Cantwell.[568] In 123 cases in which sulfonamide drugs were not used there were nine infections. In 56 cases in which there was oral and local administration of sulfonamide drugs, there were six infections. In other words, the first group showed less infection. Consequently, "thorough surgical debridement and mechanical cleansing of the wound followed by complete rest of the devitalized tissue is still of primary importance."

SPECIAL FRACTURES

Orthopedic surgeons are frequently confronted with the problem of patients with "snapping jaws." Injection of sclerosing solutions into the joints has not been satisfactory, and neither has excision of the floating cartilage. H. N. G. Hudson[569] has described an operation which seems to offer some hopeful promise. The temporomandibular joint is exposed by a curved incision and the capsule is cut by a vertical incision. The cut edges are then overlapped and sutured together. Also a pleat is taken in the capsule at the base of the zygomatic process. The patients can open the mouth without "clicking," but there is a persistent tendency for the point of the jaw to deviate toward the side operated on whenever the mouth is opened widely.

A statistical study of the fractures which occurred in the Richmond, Calif., shipyards in two and a half years was made by C. C. Cutting, L. D. Fisher and N. Neadoff.[570] One third of all the fractures occurred in the hands (metacarpals and phalanges) and more than one fourth occurred in the feet (metatarsals and phalanges). The sternum and the ribs accounted for 5.7 per cent of the fractures, fractures of the leg occurred in 2.4 per cent of cases and fractures of the spine in 2.4 per cent of cases.

[ED. NOTE: Fractures of the hands and the feet are common in most heavy manufacturing industries, but it is surprising how few fractures of the major long bones occurred in this series. Undoubtedly modern safety measures are truly effective, especially since the Liberty ships built at Richmond were fabricated by unskilled emergency labor.]

Athletic injuries are likewise on the decrease, as attested by W. A. Hanson and G. W. Hauser.[571] In a study of 300 football

568. Wilson, M. J., and Cantwell, A. R.: The Prevention of Infection in the Treatment of Compound Fractures, Bull. New York M. Coll., Flower & Fifth Ave. Hosps. **8**:18-20 (April-June) 1945.

569. Hudson, H. N. G.: Operation for Recurrent Subluxation of the Temporo-Mandibular Joint, Brit. M. J. **2**:354 (Sept. 15) 1945.

570. Cutting, C. C.; Fisher, L. D., and Neadoff, N.: Survey of Over 13,000 Fractures in Employees of Richmond Shipyards, California & West. Med. **63**:216-218 (Nov.) 1945.

571. Hanson, W. A., and Hauser, G. W.: Common Injuries Associated with Football at the University of Minnesota, Minnesota Med. **28**:755-758 (Sept.) 1945.

players at the University of Minnesota during the period from 1942 to 1945, there were no serious cranial or abdominal injuries. There were 2 cases of minor acromioclavicular separations, 2 instances of fractured ribs and 1 fracture separation of the seventh costal cartilage. There was 1 case of fracture of lumbar transverse processes. One dislocation of the elbow occurred, and there were 3 fractures of the carpal scaphoid, 8 fractures of the bones of the hand, 2 fractures of the tibia and 1 fracture of the nose. No serious accidents occurred to the ankles because they were well strapped before games, but there was an increase in injuries to the knee probably because the ankles were so well protected that the knees became the point of maximal strain.

Another special group of fractures following parachute jumps was described by P. A. Knepper.[572] Casualties were as high as 10 per cent when training began, but as more effective precautions were taken this casualty rate was reduced to less than 1 per cent. There were 7 compression fractures of vertebrae, 6 skull fractures, 79 fractures of the lower extremity and 50 fractures in other parts of the body. The fractures in the lower extremity are easy to explain on the basis of difficulties in landing.

HEALING OF FRACTURES

A method of determining healing by sound conduction is described by J. L. Weissberg.[573] A tuning fork of 128, 256 or 512 frequency is placed against a bony prominence distal to the fracture and a stethoscope is placed on a bony prominence proximally. Comparison with sound transmission on the unfractured side yields evidence of the progress of healing and can be computed on a rough percentage basis. The author states that this is especially useful in the femur.

Metabolic changes in patients with fractures were studied by J. E. Howard.[574] After fractures, healthy vigorous males suffer large losses of protein from the body which are not due to faulty absorption, the mechanical effects of immobilization or inadequate intake of vitamins. Rather there seems to be a disturbance in the normal exchange of nitrogenous constituents between the cells and their external environment. The large retention of potassium after such injuries may have some relation to physical fitness and the rate of recovery. Already debilitated patients do not show similar losses of nitrogen after fractures. It seems that during the first two weeks after the accident

572. Knepper, P. A.: Parachute Fractures, Surg., Gynec. & Obst. **81**:53-55 (July) 1945.

573. Weissberg, J. L.: Evaluation of Bone-Continuity by Sound Conduction, Bull. U. S. Army M. Dept. **4**:471-474 (Oct.) 1945.

574. Howard, J. E.: Metabolic Observations on Convalescent Patients from Fractures, Tr. A. Am. Physicians **58**:162-170, 1944.

forced feeding of nitrogenous foods is not essential to recovery and might conceivably be harmful.

J. Roche and Mme. R. Martin-Poggi [575] studied healing fractures in guinea pigs and found that two chemical substances operate at two distinct phases of the healing of the fracture. Ascorbic acid plays an important role in organization of the matrix through its action on development of connective fibers. Immediately before oxidation phosphatase shows its maximum activity. Each substance acts at a definite stage in the process.

Experiments on the effects of radiation on fracture healing were discussed by L. Y. Stefanenko.[576] The author found in experimental fractures in rabbits that trypan blue introduced into the blood stained the spinal cord in the areas corresponding to the involved extremity. Ultraviolet irradiation of the skin increased the rate of healing by its action on the sympathetic nervous system. On this basis, quartz lamp irradiation was used over the fracture in 120 cases. The author stated that healing took place in thirty-seven days in closed fractures, forty days in open fractures and forty-five days in gunshot fractures.

Other observations on the effects of the sympathetic nerves on healing of fractures were made by E. Bohm and G. Flyger.[577] It was assumed that the pain of fractures induced a vasomotor reflex or vascular cramp around the site. This leads to edema and articular stiffness. In the region of joints, injection of procaine hydrochloride prevents pain and tends to hasten healing. The authors fractured the fibula in rats and, in one group, administered 0.2 cc. of 1 per cent procaine hydrochloride into the site of the fracture. Injections were given daily for one week, on alternate days in the second week and every third day during the third week. Hyperemia at the site of the fracture set in more promptly in the animals that received injections of procaine hydrochloride. Healing was more rapid in this group also and consolidation of the callus was completed earlier.

575. Roche, J., and Martin-Poggi, R.: Sur les roles de la vitamine C et de la phosphatase dans la formation de la substance osseuse au niveau des cals de fracture, Compt. rend. Acad. d. sc. **213**:668-670 (Nov. 10) 1941.

576. Stefanenko, L. Y.: New Developments in the Treatment of Fractures, Khirurgiya, 1944, no. 10, pp. 97-104.

577. Bohm, E., and Flyger, G.: The Influence of Local Injections of Procaine Hydrochloride on the Healing of Fractures, Acta chir. Scandinav. **89**:97-112, 1943.

(*To Be Continued*)